Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/journalfranklini166fran

THE JOURNAL

OF THE

FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Dr. H. W. Jayne, Chairman; Mr. Edwin Swift Balch, James Christie, Dr. Persifor Frazer, Mr. Louis E. Levy, Committee on Publications; with the Assistance of Dr. Wm. H. Wahl, Secretary of the Institute.

VOL. CLXVI.—Nos. 991-996

(83d YEAR.)

JULY—DECEMBER, 1908.

PHILADELPHIA

Published by the Institute, at the Hall, 15 South Seventh Street.

1908

T
1
F8
v.166

621357
24.10.55

JOURNAL OF THE FRANKLIN INSTITUTE

Vol. CLXVI.—July—December, 1908.

INDEX

Accounting machine, development of the. (Burd).....177
Accounting, mechanical. (Jones).....183
Acetylene rules modified by the National Board of Fire Underwriters...469
Aluminum carbide, formation and preparation of. (Matignon).....203
Alumni Association of the FRANKLIN INSTITUTE.....403
Art students, ten thousand dollars awarded.....79

Ballentine's method of testing the hardness and density of metals. FRANKLIN INSTITUTE report.....447
Barrels, America uses many.....146
Bates, Putnam A. The equipment of farms and country houses with electricity 47
Bismuth, domestic production of.....402
Book-keeping and accounting, Burrough's system, Latest development in. (Burd and Jones).....177, 183

BOOK NOTICES—

Carpenter, R. C. and H. Dedrichs. Internal combustion engines.....487
Claudel, J. Hand-book of mathematics.....240
Duff, A. W. Text-book of physics.....486
Forsythe, Robert. The blast-furnace and the manufacture of pig-iron...80
Gibson, Geo. H. Steam, its profitable utilization.....408
Judson, W. P. Road preservation and dust prevention.....487
McCullough, E. Reinforced concrete.....488
Noyes, William A. Kurzes Lehrbuch der organischen Chemie.....239
Penrose's Pictorial Annual, the process year book, 1907-8.....240
Smith, Edgar F. Electro-analysis.....80
Stahl und Eisen. Gesammt-inhaltsverzeichnis, 1881-1906.....320
Borax industry in 1906.....394
Buhrstones and millstones.....296
Bullet, Spitzer, evolution of. (Hartmann).....165
Burd, R. L. Development of the accounting machine.....177

Cement—its use and abuse. (Lesley).....131
Coal fields, investigations of.....237
Coal production, report on.....100
Colorado, gold and silver output.....401
Copper mining in the American colonies, notes on. (Wherry).....309
Creosote oil, the process of producing.....162
Cross-ties, use of, in 1906.....100

Elements, the transformations of the. (Keller).....213
Evaporation, Notes on theory and practice of. (Sadtler).....291, 395
Explosives, the progressive decomposition of gun-cotton during its storage. (Silberrad and Farmer).....471

Farms and country houses, equipment of, with electricity. (Bates).....47
Feldspar, production of, in 1906.....176
Filtration works. (Trautwine).....363
Fir, white, as pulp wood.....225
Forest fire, timber owners organize to fight.....130

Franklin Institute:—
Alumni Association.....403
Committee on Science and the Arts. Report: Delany's "Telepost".....320
Ballentine"s method of testing the hardness and density of metals...447
Mining and Metallurgical Section. Presidential address. (Outerbridge)..353

Garnet, abrasive, production in 1906.....290
Geological survey, United States, annual report of the director.....196
Gun-cotton, Progressive decomposition of, during its storage. (Silberrad and Farmer).....471

Hartmann, L. H. The theory of shooting and the evolution of the Spitzer bullet.....165
Haupt Lewis M. "A wheel in the middle of a wheel," waterway legislation.....147
Hepburn, Joseph Samuel. The modifications of the Kjeldahl method for the quantitative determination of nitrogen.....81
Hixon, Hiram W. The relation of magmatic waters to volcanic action..297

Job, Robert. Economy in purchasing supplies.....357
Jones, Thomas M. Mechanical accounting.....183
Keller, Harry F. The transformations of the elements.....213

Lesley, Robert W. Cement—its use and abuse.....131
Lloyd, R. Louis. Electricity in refrigeration.....453
Lumber production of the Lake States, report of.....452

Magnesite, production of, in 1906.....236
Maple products, history, manufacture and analysis of. (Sy)....249, 321, 433
Matignon, Camille. Formation and preparation of aluminum carbide....203
Metals, precious, in Washington.....188
Metals, precious, mined in 1906 in Southern Appalachian States.....356

Microscope, an improved. (Teal).....197
Millstones and buhrstones.....296
Mineral production of the United States in 1906.....446

Navigation, new aids to. (Wetherill).....227
Nitrogen, The modification of the Kjeldahl method for the quantitative determination of. (Hepburn).....81
Northrup, Edwin F. Standardization apparatus for measuring volts, amperes and watts.....101
Northrup, Edwin F. Use of analogy in viewing physical phenomena.....1

Outerbridge, A. E., Jr. Opening address, president of the Mining and Metallurgical Section.....353

Photography in Philadelphia, brief notes on the early history of. (Rigling).....315
Physical phenomena, use of analogy in viewing. (Northrup).....1
Publications received.....239, 319, 488
Pulp wood, Engelmann spruce as.....238
Pulp wood, white fir as.....225
Pumice in the United States.....190
Puschin, N. Quantitative separation of tin from manganese, iron and chromium by electrolysis.....281
Pyrite industry in 1906.....355

Quartz, crystalline, production of in 1906.....176

Refrigerating industries, first international congress of.....226
Refrigeration, electricity in. (Lloyd).....453
Ridpath, J. W. Photographing water in motion.....191
Rigling, Alfred. Brief notes on the early history of photography in Philadelphia.....315

Sadtler, Philip B. Notes on theory and practice of evaporation....291, 395
Silberrad, M. M. O., and Farmer, R. E. Explosives. The progressive decomposition of gun-cotton during its storage.....471
Shooting, theory of. (Hartmann).....165
Spruce, Engelmann, as a pulp wood.....238
Storage batteries, increasing use of.....46
Sulphur and pyrite industry in 1906.....355
Supplies, economy in purchasing. (Job).....357
Sy, Albert P. History, manufacture and analysis of maple products, 249, 321, 433

Taylor, Edward R. Natural and artificial conservation of water power for electrical purposes.....409
Teal, Frank. An improved microscope.....197
"Telepost," the. FRANKLIN INSTITUTE report.....320
Tin, quantitative separation of, from manganese, iron and chromium by electrolysis. (Puschin).....281

Transvaal gold production.....100
Trautwine, John C., Jr. The water supply of Philadelphia, with special reference to the Filtration works now under construction.....363
Trees as crops 362

Volts, amperes and watts, standardization apparatus for measuring. (Northrup) 101

Washington, precious metals in.....188
Water in motion, photographing. (Ridpath).....191
Water power, natural and artificial conservation of, for electrical purposes. (Taylor) 409
Water supply of Philadelphia. (Trautwine).....363
Waters, magmatic, relation of to volcanic action. (Hixon).....297
Waterway Legislation. (Haupt).....147
Wetherill, Henry Emerson. New aids to navigation.....227
Wherry, Edgar T. Notes on copper mining in the American colonies...309
Wood preservation 162

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 1 83RD YEAR JULY, 1908

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

Section of Physics and Chemistry.

(Stated meeting held Thursday, April 23, 1908.)

Use of Analogy in Viewing Physical Phenomena.*

BY EDWIN F. NORTHRUP, PH.D.

The student who seriously takes up the study of physical science finds confronting him an immense accumulation of recorded facts, extensive treatises dealing with the "principles of physics," long shelves filled with transactions of learned societies, and mathematical expositions that seem hopelessly beyond his comprehension. If he is not to be discouraged at the outset, he will select a relatively contracted area for his mental explorations. Furthermore, taste or circumstances will shape his purpose, more or less definitely, to study the science for its own development, for the instruction of others or for the practical end of its application to engineering. If with any of these objects in view, he is des-

*Read by title.

tined to worthily add his share to progress, he will ponder the full import of the word, *οἰκονομία*. This Greek word means management of a household. But the student of physics must translate it to signify the management of the mental household, or *brain economy*.

No mind, however powerful, can hold in memory more than a small fraction of its own, or the experiences of others, not even in a highly specialized branch of science. Now, indeed, even the principles of physical science have reached a list which is difficult to reproduce in thought. Therefore, it is imperative that along with the study of physical science should go the study of how the mental efforts may be economized. There should be constant endeavor to learn how to *potentially* understand much and throw the least burden upon memory.

By what methods, then, should the study of physics be pursued that with the best mental economy, the greatest acquirements may follow? In answer to this inquiry it is commonly asserted, that the attention should be directed to the laws and principles of the science, in the application of which the infinite particular cases, that would overburden the memory, may be cared for and comprehended. While admitting the full force of this reply it still appears to be incomplete and not fully satisfying. Moreover this reply is chiefly applicable to the so-called exact sciences in which phenomena have been embraced in a body of laws and principles. In the sciences of biology, geology, meteorology and their like, the principles and generalizations are few while phenomena that attract direct study are innumerable. In physical science, on the other hand, principles and laws are almost wholly embodied and expressed in systems of differential equations. If with the idea of mental economy in view, the attention is to be attracted chiefly to laws and principles, these would be found embodied best in equations, and the student of physics would become a student of mathematics—supplied perhaps with the tools of analysis but with a mind unfurnished with images of phenomena, and with his powers of creation and discovery undeveloped. Without hoping to give an adequate reply to the inquiry put, as to what methods should be used in the study of physics to secure the best mental economy, one phase of a partial answer will be discussed in the following pages. Our theme may be outlined in the statement: *That, in studying physical science, a fruitful brain*

economy will best result by establishing the habit of mentally associating phenomena, belonging in groups and classes, according to their natural physical connections and the analogies that exist among them.

The descriptive sciences, biology, geology, and their sub-classes, have been enriched by discoveries in physics and are constantly receiving assistance from her hands. In these sciences, in which mathematical deductions and the formulation of exact laws are seldom possible there goes, along with the unwearied accumulation of observations, an association of the similar, the like, the analogous. From the data associated together judgments are formed and the methods of nature are described. But are the descriptive sciences, with their borrowing, in debt to physics? If physics claims her own, may she not take in return from these sciences ideas and methods, as payment for the exact reasoning and laws that she gives? If physics is not to become barren in discovery, and end as a science of differential equations, we believe she needs to take and use the fertile, data-collecting and associative methods of the descriptive sciences. In these sciences, observation, comparison, and analogy are the constant fruitful aids to their development.

We shall now endeavor to show to any one entering upon the serious study of physical science, in a treatment that is illustrative rather than argumentative, the value of the methods suggested above.

MEANING AND NATURE OF ANALOGY.

Thought moves on in time, as a bee in space, in a generally tortuous course, passing from one mental image to another, from one abstraction to another. Memory joins the image of the moment with those of moments passed. A mental pleasure is felt, and the past and present are more securely linked in memory, whenever the mind discovers that one image or one concept has a likeness, in form, color, or character, with others that it has had before. And this pleasure and impress are fullest, when among many images or concepts, a single element is discovered, like honey found in flowers, that is common to many or all. Witness is ever given in speech and literature of the mind's tendency to seek among its concepts those elements that are like, similar, or analogous. Thus,

referring to the turning of water into wine, Milton won a prize in the University for writing the single line:

"The conscious water knew its Lord and blushed."

Acknowledgment was given to the merit of perceiving a beautiful and delicate analogy. Similitudes and analogies are employed by all the masters in literature. Shakespeare makes Polonius say,

"To thine own self be true,
And it must follow *as the night the day,*
Thou canst not then be false to any man."

Here the analogy of night following day, is used to illustrate and impress the certainty with which the result of not being false to any man, must follow, if one is true to himself.

The psychological value of these literary analogies, as Herbert Spencer has pointed out in his Essay on Style, is gain in economy of thought. They give, with the minimum attention to the symbols of thought, the maximum of mental impression. In popular jargon and much literature we find the words: likeness, similarity, analogy, loosely used to have the same significance. But when science replaces literature, all the clearness and precision that it is possible to give to the meaning of words must be observed.

When the word, *analogy,* is to be used carefully and in a scientific sense, it may be best defined as the exact translation of its Greek original, ἀνά, according to, and λόγος, proportion; which signifies, equality of ratios, or an agreement between the relations of things to one another. By this it is to be understood that two or more objects are analogous; if, when certain elements, which define them, are mentally abstracted, these are found to be equal, or in numerical relations that are proportionate.

Thus, if from the objects A and B, elements a_1, a_2, which define A and elements b_1, b_2, which define B, are mentally abstracted, the objects, A and B, are strictly analogous, in a scientific sense, if $a_1 : b_1 :: a_2 : b_2$.

Analogies used more or less precisely in this scientific sense are frequently drawn, to give an illustration, between objects or physical events. Thus the ebb and flow of the tide is compared to the swinging of a pendulum. Here the mind abstracts from the object, tide, the elements, height of water level and time of day, and from the object, pendulum, the elements, elongation and time,

and the two are considered to be analogous, because height of water level has somewhat the same relation to time of day as has the elongation of the pendulum to its time of swing.

Literature employs with advantage loose analogies based upon equality of the relations of elements of an accidental character, and often quite special to the particular objects compared. But the analogies used in science, to have scientific value, must be chosen so that exactly definable proportions may be stated between relations of elements that may be themselves precisely defined. We are thus lead to inquire more fully what constitutes in a scientific sense a perfect analogy.

Let P_1, P_2, P_3 - - - P_n stand for a set of phenomena. If examined minutely, each of these phenomena will be found to consist of a limitless number of elements. In the evolutionary progress of physical science certain of these elements have been observed to be as repeatedly presented as the phenomena recur. Hence certain elements, belonging to any one of the phenomena, have been considered as being elements that are characteristic of the phenomenon, and therefore suitable to use in defining and in describing it. When a phenomenon is considered these characteristic elements are mentally abstracted from the rest. Then the elements and the relations found to exist between them are stated in precise language and the phenomenon thus becomes defined, and may be described to others. In the descriptive sciences, biology, geology, etc., the characteristic elements and the relations among them are generally defined verbally or graphically represented. As the relations cannot be given with numerical precision, these sciences cannot be classed as exact sciences and the analogies among their various phenomena can be drawn only loosely. In the physical sciences, however, the relations between the characteristic elements of a phenomenon can be expressed with numerical precision, as relations between constants, variables, and differential coefficients of variables; and the relations so expressed generally take the form of differential equations.

If the differential equations, expressing the relations that exist between the characteristic elements of each of the phenomena, P_1, P_2, P_3 - - - P_n, are of the same form and number for each of the phenomena, then the phenomena form what may be termed a group of perfect analogies. By the same form, it is to be understood that they are alike in form, in respect to their variables,

to the derivatives of their variables and to the constants that figure in the different terms. The above statements will be illustrated and made clear by the following physical example:

Let Fig. 1 represent a right section of a cylinder of very great length and radius, R. Now this cylinder may become the seat of various phenomena, $P_1, P_2, P_3 - - - P_n$, depending upon the assumptions that are made respecting it. By making proper assumptions some of the phenomena may be made to form a group of perfect analogies. Let assumptions be made that will yield a group of three analogous phenomena, P_1, P_2, and P_3. For this purpose conceive the cylinder to be filled with a conducting, incompressible fluid of density, ρ; mercury, for example, and confined in a very thin cylindrical wall.

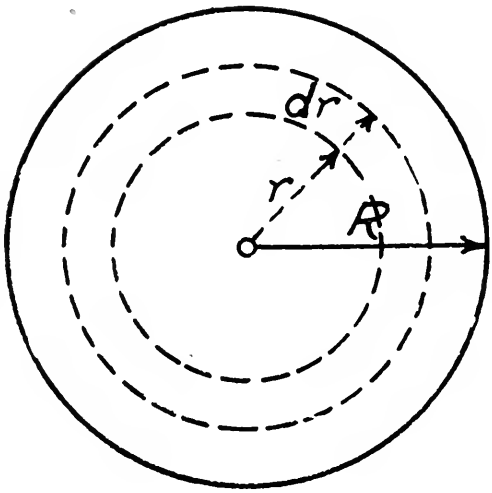


Fig. 1

Suppose the phenomenon, P_1, is the difference, g, in the hydrostatic pressures between the axis of the cylinder and its circumference; this difference in pressures being due solely to the gravitational attraction of the mass of the fluid. Suppose the phenomenon, P_2, is the difference, g_2, in the hydrostatic pressures between the axis of the cylinder and its circumference; this difference in pressures being due solely to the passage through the cylinder, parallel to its axis, of an electric current of current density I_1. Finally conceive the cylinder to revolve upon its axis with an angular velocity, ω, and let the phenomenon, P_3, be the difference, g_3, in the hydrostatic pressures between its circumfer-

ence and its axis; and that this pressure-difference is due solely to the centrifugal forces set up by the rotation of the cylinder.

Now it may be easily shown that for the phenomenon, P_1, we have,

$$dg_1 = -2\pi M^2 r\, dr, \tag{a}$$

or integrating from the axis to the circumference,

$$g_1 = -2\pi M^2 \int_0^R r\, dr = -\pi M^2 R^2 \tag{b}$$

In (a) and (b) M is the number of gravitational units of mass, per unit of volume, in the cylinder, and we are to take the negative sign to mean that the direction of the force acting to produce the pressure difference is in the opposite direction in which r is taken to increase, that is, the pressure is directed toward the axis.*

We have, similarly, for the phenomenon, P_2,

$$dg_2 = -2\pi I_1^2 r\, dr \tag{c}$$

or integrating from the axis to the circumference,

$$g_2 = -2\pi I_1^2 \int_0^R r\, dr = -\pi I_1^2 R^2 \tag{d}$$

Here the negative sign has the same significance as before.†

For the phenomenon, P_3, we may deduce the values of dg_3 and g_3 as follows:

The mass contained in an annular cylinder of unit length, of inside radius, r, and radial depth, dr, is,

$$dm = \rho \,.\, 2\pi r\, dr$$

The centrifugal force exerted by the mass, dm, acting radially outward from the axis is,

$$d\,F = \omega^2 r \,.\, 2\pi \rho r\, dr,$$

and the hydrostatic pressure, or pressure per unit of area at a distance, r, from the axis is,

---

*See Forces in the Interior of an Electric Conductor, by E. F. Northrup, Phys. Rev., p. 490, June, 1907.

†See Ibid. p. 487.

$$\frac{d\,F}{2\,\pi\,r} = d\,g_3 = \omega^2\,\rho\,r\,dr \tag{e}$$

If (e) is integrated from the axis to the circumference of the cylinder, we shall have the difference in pressures, g_3, between the circumference and the axis. Thus,

$$g_3 = \omega^2\,\rho \int_0^R r\,dr = \frac{\omega^2\,\rho\,R^2}{2} \tag{f}$$

Here we are to understand by the positive sign that the direction of the pressure is that in which r increases, the pressure being greatest at the circumference.

Remembering that g_1, g_2, g_3, are *differences* in pressures, we can now write the following perfectly analogous relations, where A_1, A_2, A_3, and B_1, B_2, B_3 are constants.

$$dg_1 = -\,2\,\pi\,M^2\,r\,dr = A_1\,M^2\,r\,dr \tag{g}$$
$$dg_2 = -\,2\,\pi\,I_1^2\,r\,dr = A_2\,I_1^2\,r\,dr \tag{h}$$
$$dg_3 = \rho\,\omega^2\,r\,dr = A_3\,\omega^2\,r\,dr \tag{i}$$

and

$$g_1 = -\,\pi\,R^2\,M^2 = B_1\,M^2 \tag{j}$$
$$g_2 = -\,\pi\,R^2\,I_1^2 = B_2\,I_1^2 \tag{k}$$
$$g_3 = \frac{\rho\,R^2}{2}\,\omega^2 = B_3\,\omega^2 \tag{l}$$

In the equations (g)—(l), we have the differential and integral mathematical expressions for the three phenomena, P_1, P_2, P_3, which constitute a group of perfect analogies. The corresponding elements, dg_1, dg_2, dg_3, of the three phenomena are to be classed as effects that are due to certain causes. In the group chosen these effects are identities in respect to quality or nature, but of possible difference in magnitude.

M^2, I_1^2, ω^2 are the causes of the effects and form a group of corresponding elements. The constants, A_1, A_2, A_3 enter the equations in like manner as do the variables, r and dr.

In the integrated expressions, g_1, g_2, g_3, are corresponding elements, constituting the effects, M^2, I_1^2, ω^2, are corresponding elements constituting the causes, while B_1, B_2, B_3, are constants that enter the terms in the same manner.

By paraphrasing a statement of M. Petrovitch* we may generalize the above as follows:

Let P_1, P_2, P_3—P_n, constitute a group of n phenomena. Then form the table,

$$\begin{array}{cccc} \alpha_1 & \alpha_2 & \alpha_3 & ---- \\ \beta_1 & \beta_2 & \beta_3 & ---- \\ \gamma_1 & \gamma_2 & \gamma_3 & ---- \\ - & - & - & ---- \end{array}$$

of all the elements used to define all the phenomena, including the constants, variables, and differential coefficients of variables. The jth line will now contain the elements of the phenomenon, Pj. Then the notion of a perfect analogy between all the phenomena of the group implies the possibility of passing from the equation of any one phenomenon of the group to any other phenomenon of the group, by changing without varying the order, all the elements of any line of the table into all the elements of any other line of the table. The elements in the same column constitute, then, corresponding elements.

As it will be helpful to the development of our subject to bring into contrast the mathematical and the physical methods of stating and using analogies, we shall now give in turn some illustrations of each method.

ANALOGIES REGARDED AS RELATIONS BETWEEN MATHEMATICAL EXPRESSIONS.

The conclusion will be drawn from the view given above, as to what constitutes a perfect analogy, that all phenomena are strictly analogous that can be expressed by the same equations, when for each phenomenon considered the proper significance is given to each of the symbols of the equations. We shall assume that different groups of analogous phenomena may be expressed by equations of different forms, and that these equations having different forms may be arranged and classified according to a system that is based upon the greater or less correspondence of their characteristic terms. A general scheme or system of differential equations might be thus formulated, into which may be fitted allied groups of analogous phenomena.

Such classifications or schemes of differential equations have

*La Mécanique des Phénomènes fondée sur les Analogies, p. 8.

been formulated, notably by M. Petrovitch in the suggestive work referred to above. He points out that the few fundamental notions needed for the formulation and understanding of such a scheme has value in giving a clear insight into physical relations, in suggestiveness for lines of research, and in offering a philosophical view of physical relations that is not without interest because of its generality. He says:*

"Such a scheme will be truly called a new branch of natural philosophy destined to progressively and indefinitely enlarge, the object of which will be the study of the general mathematical relations between causes and their effects disembarrassed from all particularities that specially attach to such or such particular kind of phenomenon."

A scheme of this character contemplates an extensive classification of analogous phenomena into groups, in which each group is expressed by one or more differential equations of particular forms, the equations giving the relations that maintain between what are judged to be the characteristic elements of the phenomena. To make this manner of viewing physical relations quite clear we shall give examples of a few prominent groups of analogous phenomena, as defined by the equations which express the relations that exist between their characteristic elements.

A presentation of the physical method of viewing analogies will next be given in the form of a few examples. We shall then see how the physical method may be used to bring into view important aspects belonging to several phenomena, and we shall be in a position then to examine into the relative advantages that attach to the mathematical and to the physical methods.

From a general mathematical point of view, all phenomena may be considered as being the relations which maintain between quantities used to express causes and effects, by which the phenomena are characterized.

The characteristic elements which are mentally abstracted from phenomena and designated as the *cause,* or *causes,* of the phenomena, may be classified as forces; mechanical, electrical, magnetic, gravitational, chemical, etc.; and temperature differences. The forces may be simple forces, as a mechanical pull, or generalized forces, in the Lagrangian sense, as the moment of a couple,

*Ibid, p. 22.

a surface tension, a temperature difference, a variation of potential, etc. They may appear directly in the equations, or as explicit functions of other quantities, as time, space, gravitating matter, electric currents, and charges, magnetized matter, heat, linear or angular velocity, etc.

The characteristic elements mentally abstracted from phenomena and usually called *effects,* are: the variation with time or space of magnitudes, designated cöordinates, as a length ,a surface, a volume, an angle, magnetic flux, current flux, heat flux, etc. When we speak of phenomenal effects the idea of change or variation is usually present to the mind. Thus in speaking of the Hall effect, we think of the deflection of an electric current within a conductor. In the Thomson effect there is the evolution or absorption of heat caused by the electric current in flowing from one point in the conductor to another at a different temperature. Likewise the Peltier effect is the *change* in temperature produced at the junction of two dissimilar metals through which current passes.

If the effect is a variation in a quantity which varies only as a space cöordinate is made to vary, the notion of time not being involved, though the effect produced by the cause or causes may assume an infinite variety of forms, it is always something accomplished by forces acting through space, and hence may be considered as some form of work. Thus the change in level of mercury in a barometer, when this is taken to different heights, is a phenomenon in which the effect is the variation of the mercury column; work being done on or by the mercury as the space cöordinate, elevation above sea level, is changed.

Now following, in part, a method of procedure suggested by Petrovitch, write the following equation:

$$\Omega \frac{d\,\alpha}{d\,\mu} - (F_1 + F_2 + F_3 + \cdots) = 0 \qquad (1)$$

The mathematical form of this equation indicates that a certain magnitude, α, varies in respect to another magnitude μ and, that this variation of α in respect to μ, is proportional to the sum of the quantities, F_1, F_2, F_3---etc. We could with greater generality express the variation in α as the sum of the variations of its three rectangular components, but for the sake of simplicity we shall

treat α as a function which varies only when a single cöordinate varies.

We shall take in this equation F_1, F_2, F_3, etc., to represent the numerical magnitudes of any finite number of simultaneously acting causes which produce a single effect, which is the variation of an element, α, mentally abstracted from a phenomenon, when an arbitrary variation occurs in a chosen magnitude, μ. The quantity μ will be chosen to vary uniformly, so that $d\mu$ is always constant.

The element α, mentally abstracted from a phenomenon, may be either what we shall designate, a primary element or a derived element. By primary element we shall understand one that cannot be further decomposed in thought. It may then be treated as a quantity, representing an elementary concept, as space, a quantity of electricity, or a quantity of heat. It is then a single cöordinate that varies only when μ varies. When α is a derived element it will be a quantity which is related by one or more equations of union to another element taken as the primary element. If there is but one equation of union α will have the character of a velocity, or a current of electricity. It will then be the variation of the primary element from which it is mentally derived, as a current of electricity is the variation of a quantity of electricity with time. Its first derivative in respect to μ will equal the second derivative in respect to μ of the primary element. Hence when α is a derived element there exists at least one invariable relation as,

$$\alpha \, d\mu - d\varepsilon = 0 \tag{2}$$

in which ϵ designates a primary element mentally abstracted from any phenomenon and stands for a cöordinate or numerical value that can be measured in terms of a unit of like kind.

When α is a derived element, joined with ϵ by equation (2) we shall call Ω, in analogy with mechanics, a *coefficient of inertia.* When α is a primary element we shall call Ω a *coefficient of restraint.* The full significance of the designations given above will appear in what follows.

Equation (1) is instinctively felt to present a relation that holds generally in nature, inasmuch as it is constantly observed that the magnitudes of effects are proportional to the sum of the intensities of all causes which simultaneously act to produce them. In the form, however, in which the equation stands it is entirely general

and without definite physical significance. But according to the designations given to the different symbols and the choice made of the causes, F_1, F_2, F_3, etc., it may be made to assume different forms, each of which will stand for a group of analogous phenomena. Before giving illustrations of some of the various forms the equation may take and the groups of phenomena embodied in them it will be found advantageous to make a few simple transformations of this equation, upon which some comments may be profitably made. In making the transformations, use will be made of the invariable relation given in equation (2).

From equation (2), $\alpha = \dfrac{d\,\varepsilon}{d\,\mu}$

and, $\dfrac{d\,\alpha}{d\,\mu} = \dfrac{d^2\,\varepsilon}{d\,\mu^2}$

Transpose the second term of Eq. (1), multiply both members by $d\,\varepsilon$, and replace $\dfrac{d\,\alpha}{d\,\mu}$ by its value $\dfrac{d^2\,\varepsilon}{d\,\mu^2}$, then integrate the resulting equation when we shall have

$$\Omega \left(\frac{d\,\varepsilon}{d\,\mu}\right)^2 = 2 \int (F_1 + F_2 + F_3 + \cdots)\, d\,\varepsilon + c_1 \qquad (3)$$

or,

$$\Omega\, \alpha^2 = 2 \int (F_1 + F_2 + F_3 + \cdots)\, d\,\varepsilon + c \qquad (4)$$

where c is the arbitrary constant of integration.

Now, assume that $F_1 + F_2 + F_3 + \cdots$ can be expressed by a single quantity, F, and, further, that $F\, d\,\epsilon$ is the exact differential of an arbitrary function Π. Then $\Pi = \int F\, d\,\epsilon + c_1$, and we shall have,

$$\Omega\, \alpha^2 = 2\,\Pi + K \qquad (5)$$

where c_1 and K are arbitrary constants resulting from the integration. Equation (5) is the integral form of the "theorem of living forces" first given by Laplace.* The quantity, $-\Pi$, is now known under the name of the potential function.

Equations (1) and (5) embody the mathematical relations that maintain between the characteristic elements of a vast num-

*Livre I, Sec. 19, of the Traité de Mécanique Céleste.

ber of physical phenomena. But before they can become available for expressing physical relations they must be made to assume particular forms that are based upon particular assumptions. Any particular form of equations (1) or (5) will express a group of analogous physical phenomena, and by giving particular meanings to the symbols of any particular form of these equations the relations between the characteristic elements of a particular phenomenon may be expressed.

In order to assign particular forms to equation (1), we must first consider, briefly, the general character of the causes, F_1, F_2, F_3, etc., upon which the effects depend. These causes may be broadly divided into *active* causes and *passive* causes. By active causes we shall understand those which act to initiate or continue the effect, $\Omega \frac{d\alpha}{d\mu}$, and when proceeding from sources external to the object of the phenomenon will be expressed by giving to F_1, F_2, F_3, etc., a positive sign. Such causes will be mechanical, gravitational, electric and magnetic forces, temperature, light and sound intensities, etc.

By passive causes is meant those which act in direct opposition to the active causes and hence tend to diminish the effect. These will be expressed by giving F_1, F_2, F_3, etc., a negative sign. Such passive causes may be external to, or contained in, the object of the phenomenon, or both. Examples of these are, molecular and mechanical friction, magnetic damping, electrical resistance, magnetic reluctance, electric and magnetic hysteresis, resistance to heat conduction, thickness of a medium which has opacity for the transmission of any kind of radiant energy; or in general terms, anything which tends to bring about the final cessation of an effect.

The active causes may be constant in their manifestation, or, they may vary, being functions of a quantity which is taken as the independent variable. This last may express such concepts as time, space, mass, electricity, magnetism, temperature, heat, etc.

The passive causes may likewise be constant, or functions of the element α, or its differential coefficients, or both.

In nature phenomena, as observed on the earth, never occur without the presence, to a greater or less extent, of passive causes; this statement being only another way of saying that perpetual motion is impossible, for all effects, initiated by active causes,

must finally cease through the action of passive causes. It follows that any mathematical expression which expresses the relations between what are considered to be the characteristic elements of phenomena and which contains no terms expressive of passive causes, can only be a more or less close approximation to the relations actually existing on the earth. Equation (5) is such an expression. It appears very generally in the treatment of mechanical problems and in discussions upon theoretical mechanics. We may therefore pause in our discussion to make the following remarks: If we differentiate Equation (5), we have,

$$d\frac{\Omega\, a^2}{2} = d\, \Pi = (F_1 + F_2 + F_3 + \cdots)\, d\, \varepsilon \qquad (6)$$

This states that the variation of $\frac{\Omega\, a^2}{2}$, which is an expression for kinetic energy, exactly equals the variation of a function of the forces, Π, or of the potential function $-\Pi$, it being remembered that this function can only exist when the forces depend exclusively upon variables that determine the state of the system. In equations (5) and (6) only one such variable, ϵ, is considered.

Now it is evident from observations made upon any mechanical or electrical system, that when the kinetic energy of the system varies, though the greater part of the energy transformed may spend itself in doing work against the forces in a manner to alter the potential of the system, a part of the transformed energy is always used up in overcoming frictional resistances and so converted into heat, and thereby lost to the system. This latter portion of the transformed energy is not embodied in equation (6). In the motions of the heavenly bodies only can it be said strictly, that the increase or the diminution of the kinetic energy of the system is closely or exactly equal to the diminution or augmentation of the internal potential of the system. In other words, in all phenomena that are observed to take place upon the earth there is, in strictness, no such principle as "conservation of living forces."

Many examples might be deduced to illustrate and prove the above statements, but the following familiar case only can be mentioned. Suppose a pendulum bob is pushed to one side from the vertical and then left free to oscillate. We should have the bob return, if equation (5) held strictly, to the lowest position

with a velocity that would carry it again to a point as high as that from which it descended. In its upward swing it would do work against the force of gravity and increase the internal potential of the system, pendulum bob and earth. This increase in potential would be sufficient so that in again diminishing to a minimum, the acquired kinetic energy would keep the bob oscillating forever. This is observed not to be the case in this instance, or any like it, and hence the approximate character of equation (5) and all physical reasoning based upon it.

By the use of proper assumptions equation (1) may be made to clearly express many groups of physical phenomena, some of which we shall now illustrate:

In equation (1) assume that α is a primary element and that only one cause, F_1, which is constant, is present. Equation (1) will then take the form

$$\frac{d\,\alpha}{d\,\mu} = \frac{F_1}{\Omega}$$

As F_1, and Ω are taken as constant quantities, the first member is constant, and calling this γ, we have,

$$\gamma = \frac{F_1}{\Omega} \tag{7}$$

This expression, identical with Ohm's law, simply states an intuitive perception that an effect manifests itself directly as the intensity of the cause producing it and inversely as the restraint furnished to its occurrence. As α is here chosen as a primary element, the effect designated by γ will be the uniform change with time of an element incapable of decomposition in thought. Thus γ will be a current of matter, a current of electricity, a magnetic flux, or a flux of heat, in which cases we shall have respectively, F_1, a mechanical force or pressure, an electromotive force, a magnetomotive force, a difference of temperature, and Ω, a mechanical resistance, an electrical resistance, the reciprocal of heat conductivity.

If α is now assumed to be a derived element, a large group of simple phenomena, which are entirely analogous, will be approximately symbolized if we give equation (1) the form

$$\Omega\,\frac{d\,\alpha}{d\,\mu} = F_1 \tag{8}$$

In this case F_1, is a constant active cause and both the equations (2) and (5) hold.

By integrating equation (8), we get

$$\Omega\, \alpha = F_1\, \mu + A_1 \tag{9}$$

and as $\alpha = \dfrac{d\,\varepsilon}{d\,\mu}$, we obtain in integrating Eq. (9)

$$\Omega\, \varepsilon = \tfrac{1}{2}\, F_1\, \mu^2 + A_1\, \mu + A_2 \tag{10}$$

where A_1 and A_2 are constants of integration.

It will be noted that as $\dfrac{d\,\alpha}{d\,\mu} = \dfrac{d^2\,\varepsilon}{d\,\mu^2}$, the effect partakes of the character of an acceleration. If the constant cause, F_1, is some species of force, as the tension of a rubber band, gravitational, electric, or magnetic force, then Ω is a coefficient which relates in some manner to the inertia of whatever the force acts upon. Now inertia is a property which belongs only to matter and ether (unless we extend the property to electrons) and Equations (5), (8), (9), and (10) can only be extended, with the assumptions made, to mechanical and ether phenomena.

If we assign the symbols the meanings,

Ω = Mass of particle
ϵ = Distance of vertical descent
α = Velocity of descent
μ = Time
F_1 = Weight of particle = $\Omega\, g$
II = $\Omega\, g\, \epsilon$, or work done by gravity;

then Eq. (8) becomes $\dfrac{d\,\alpha}{d\,\mu} = g$ and Eq. (10) becomes

$$\varepsilon = \tfrac{1}{2}\, g\, \mu^2 + A_1\, \mu + A_2 \tag{11}$$

which is recognized as expressing the law of bodies falling in vacuum. From Equation (5) we have,

$$\frac{\Omega\, \alpha^2}{2} = \omega\, g\, \varepsilon + K_1 \tag{12}$$

which states that the kinetic energy of the falling body is equal to the work done by gravity on the body in moving it a distance, ϵ, plus a constant which expresses the kinetic energy possessed by the body when ϵ is zero.

These same equations, (8) to (12), with the proper concepts attached to the symbols, will give the angular acceleration, and angle turned through of a body rotating about a fixed axis and subjected to a constant torque. Also the electric current produced by applying a constant E.M.F. to a coil of wire having self induction but no ohmic resistance.

The analogous phenomena of any group expressed by an equation can always be put in evidence by means of a table. A few of the phenomena dependent upon Equations (8) to (12) are given in table I, which will serve as a sample of how such tables may with great advantage be constructed:

TABLE I

PHENOMENON	Ω	ε	α	μ	$\frac{d\alpha}{d\mu}$	F_1	Π
Linear motion of a particle.	Mass of particle.	Linear distance.	Linear velocity.	Time.	Linear acceleration.	Constant force acting.	$F_1 \varepsilon =$ work done by force.
Circular motion of a particle distant, r, about a center, O.	Moment of inertia about O.	Length of arc.	Angular velocity	Time.	Angular acceleration.	$Fr =$ Moment of force.	$F \theta r =$ work done by force.
Flow of electric current in a coil of wire that has no resistance.	Self-Induction of coil.	Quantity of electricity.	Instantaneous Value of Current.	Time.	Change in current with the time.	Constant E. M. F.	$E \int d\varepsilon =$ work in moving Elec. in circuit.

Attention should be directed again to the facts that in nature at least upon the earth, bodies do not fall in a perfect vacuum nor rotate on a frictionless axis, and current never flows in a coil entirely devoid of ohmic resistance, and in general, that the work done by forces is never wholly expended in developing kinetic energy that remains with the system. Some of this work is expended always against passive forces as friction, resistance, hysteresis, etc. The conclusion is therefore inevitable that any mathematical expression, or system of mechanics, which states that the effects produced in phenomena are functions of active forces only, is approximate in its fundamental character.*

*In this connection one should read Chapter XII of L'Evolution de la Méchanique, par P. Duhem.

Consider next the group of analogous phenomena in which a single cause acts, which is directly proportional to the element, α. Then $F_1 = -K\alpha$ and Equation (1) assumes the form,

$$\Omega \frac{d\alpha}{d\mu} = -K\alpha \tag{13}$$

where K is a constant.

In integrating Equation (13) we obtain

$$\alpha = A e^{-\frac{K}{\omega}\mu} \tag{14}$$

where A is a constant and e the base of the natural logarithms. In Equation (13) the effect, of whatever nature, is to be taken as the variation in the characteristic element, α, chosen as a cöordinate, when the magnitude μ is made to vary arbitrarily.

If α is a primary element, that is if $\frac{d\alpha}{d\mu}$ is of the nature of a velocity, then Ω is a coefficient which determines the constant restraint put upon the effect to take place. In this case the instantaneous value of the effect will be directly proportional to the instantaneous value of the passive cause and inversely proportional to the magnitude of Ω, namely, to the constant restraint imposed upon the primary element to change.

If α is a derived element, that is, if $\frac{d\alpha}{d\mu}$ is of the nature of an acceleration, then Ω is a constant coefficient, which determine the ratio of the cause to the effect, and may therefore be taken as a coefficient of inertia. In this case, as the existing phenomenon can only have been initiated by an *active* cause, and as Equation (13) contains no expression for an active cause, $-K\alpha$ must wholly exert itself in causing a phenomenon previously produced to diminish or die out.

The law of an effect, when the only cause present is a passive cause which is proportional to the element that varies, is always expressed by a logarithmic curve, a graph of which is given in Fig. 2.

Now no event occurs upon the earth in which there is not present to a greater or less extent a passive cause that tends to make disappear a phenomenon which has been previously initiated by an

active cause. The following will serve as an illustrative example: Conceive a copper disk rotating in its own plane and turning upon its own axis between the poles of an electromagnet. Let Ω be the moment of inertia of this disk. At time, $\mu = 0$, let the disk be rotating with an angular velocity, α. It can only have attained this angular velocity through the agency of an active cause which is supposed to have ceased to act when $\mu = 0$. At this time let a passive cause begin to slow down the rotation. This passive cause will result from the magnetic flux produced by the electromagnet, through the plane of the disk, and will equal $-K\alpha$.

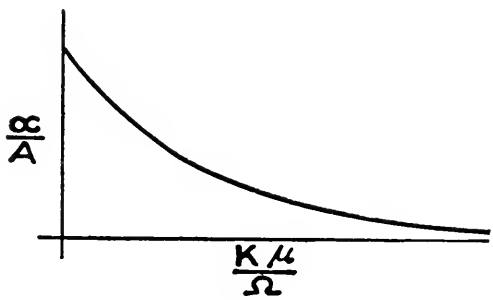


Fig. 2

If at time $\mu = 0$, the angular velocity is V, then by equation (14) the angular velocity of the disk at any time, μ, is

$$\alpha = V e^{-\frac{K\mu}{\omega}} \tag{15}$$

Here the constant, K, measures the effectiveness of the magnetic flux in producing a damping effect. At any time, μ, the angular velocity will be greater as the moment of inertia, Ω, is greater; that is the greater the coefficient of inertia, the less effective is the action of a passive cause. Now the damping effect may be very weak, resulting from a slight air friction only, but in time it is always manifested and always in one direction; namely, in opposition to the active cause which originated the motion.

Newton's law of heating or cooling of a body in still air is, in effect, that the temperature gained or lost in an element of time is proportional to the temperature difference between the body and the surrounding medium. Call α the temperature of the body above that of the medium at any time, μ. Then the variation of α as μ varies will be proportional to α itself. This relation is ex-

pressed in Equation (13). Now the effect as expressed by the law, is the variation in the temperature. The cause of this effect is the temperature gradient between the body and the medium. α will be a primary element as temperature cannot well be conceived as dependent upon a more fundamental quality. If Ω is taken as a constant quantity which is proportional to the specific heat of the body, the change in temperature with the time will be inversely as the magnitude of this quantity. We may call it therefore with propriety, a coefficient of restraint, inasmuch as it is a quantity which tends to hold back the variation in the primary element, α.

The equations (13) and (14) symbolize a group to which very many phenomena belong. Of these we may mention, merely the few following:

The variation of the barometer with the elevation;

The absorption with the time of electricity in the dielectric of a long insulated cable, after the capacity charging current has ceased, the conductor being joined to one pole of a battery, the other pole being grounded;

The variation with the distance from the generator, of the ratio of the entering current to the current at any point from the generator, on a very long telegraph line, grounded at the far end and carrying an alternating current;*

The variation with the time of the quantity of electricity which flows from a charged body earthed through a very high resistance;

A little reflection would suggest many other phenomena belonging to this group which might be mentioned.

It may be remarked that in general, any functions when multiplied by e^{-x} denotes an attenuation of the function as x increases and expresses thereby the inevitable trend of natural phenomena.

The passive cause, F_1, instead of being directly proportional to the element, α, which varies, might be proportional to any function of α. Thus the decrease in the angular velocity of the copper disk, above mentioned, due to air damping only, would be more

---

*See Eq. 24, p. 779, Elec. World and Eng., Nov. 15, 1902, art. by E. F. Northrup on "The Use and Advantages of the Alternating Current for Land Telegraphy."

nearly proportional to α^2. It would not, however, be of interest to examine here any of these functions.

An important group of phenomena occur in which the effect is produced by the simultaneous action of a constant active cause and a passive cause which is proportional to the characteristic element. In this case, if we first consider the characteristic element, α, as a derived element, Ω will be a coefficient of inertia and Equation (2) will hold. We shall then have, $F_1 =$ a constant active cause, or force, and $F_2 = -K\alpha$, so that Equation (1) assumes the form,

$$\omega \frac{d\alpha}{d\mu} = F_1 - K\alpha \tag{16}$$

The well known integral of Equation (16) is

$$\alpha = \frac{F_1}{K} + C e^{-\frac{K\mu}{\omega}} \tag{17}$$

where C is the constant of integration.*

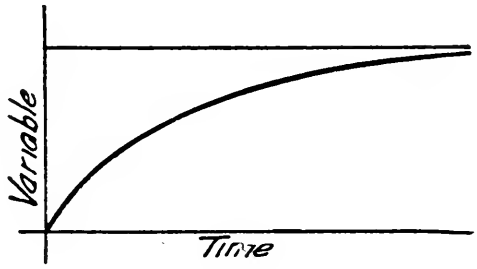


Fig. 3

A feature to be noted in this group of phenomena is that the characteristic element, α, tends to reach the constant value, $\frac{F_1}{K}$, as the independent variable, μ, increases, and approaches this value asymtotically. The graph, Fig. 3, shows these features:

A typical phenomenon of this group is the motion of a particle, of mass Ω, subjected to the accelerating action of a constant force, F_1, and moving in a medium which produces a retarding effect which is proportional to the instantaneous velocity of the particle. $\frac{d\alpha}{d\mu}$ is the acceleration of the particle where μ is the time. The case

*Lamb's Infinitesimal Calculus, p. 475.

would also be exactly met by a long strip of copper falling in the direction of its length between the poles of a magnet.

The following mechanical phenomenon will serve as another illustration of this group. Let the armature of a rotary field induction motor be direct connected to a heavy fly wheel which together with the armature has a moment of inertia, Ω. Let μ be the time elapsed after the armature and fly wheel begin to rotate. Let the magnetic field rotate with the constant angular velocity V. Let α, which it is required to find, be the angular velocity of the fly wheel at any instant, μ. Then the torque on the armature will be proportional to the difference between the angular velocity of the field, and the armature, or the torque equals $K(V-\alpha)$. The inertia of the rotating parts will act as a force in opposition to the torque, and equilibrium must maintain between these forces, so we shall have,

$$-\omega \frac{d\alpha}{d\mu} + K(V - \alpha) = 0$$

or

$$\omega \frac{d\alpha}{d\mu} = KV - K\alpha \qquad (18)$$

Since K V is a constant, Equation (18) is of exactly the same form as Equation (16).

Integrated, Equation (18) gives

$$\alpha = Ce^{-\frac{K\mu}{\omega}} + V$$

If $\alpha = 0$ when $\mu = 0$, then $C = -V$ and

$$\alpha = V\left(1 - e^{-\frac{K\mu}{\omega}}\right) \qquad (19)$$

Thus the fly wheel attains its angular velocity, which is finally equal to that of the rotary field, according to the law shown in the curve, Fig. 3.

When a constant E.M.F. is suddenly applied to the terminals of a coil having inductance and resistance only, the electric current in the coil increases with the time by the same law as expressed in Equation (16). In this case Ω is the coefficient of magnetic inertia, or of self induction of the coil, F_1, the constant E.M.F. and K, the ohmic resistance of the circuit. In familiar

symbols, C being determined so $i = 0$, when the circuit is first completed, we have

$$i = \frac{E}{R}\left(1 - e^{-\frac{Rt}{L}}\right) \tag{20}$$

It is not necessary in this group of phenomena to consider α as a derived element only. It may be a primary element, in which case Ω will be a "coefficient of restraint."

Thus according to the arrangement shown in Fig. 4, let it be required to find the variation with the time, μ, of the charge, α, in the condenser of capacity, C_1, when the constant E.M.F., F_1, is

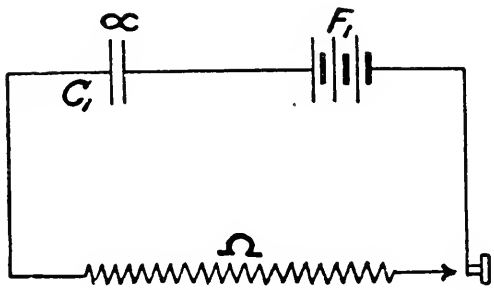


Fig. 4

suddenly applied through the high resistance, Ω, to the terminals of the condenser. If ν is the instantaneous potential to which the condenser is charged and $i = \frac{d\alpha}{d\mu}$, is the instantaneous current in the resistance, Ω, we have the relation,

$$\nu = \frac{\alpha}{C_1} \text{ and } \nu = F_1 - \omega\, i$$

or

$$\omega \frac{d\,\alpha}{d\,\mu} = F_1 - \frac{\alpha}{C_1} \tag{21}$$

Now Eq. (21) is observed to be exactly like Eq. (16) where $K = \frac{1}{C_1}$. The charge, α, is a primary element, as a quantity of electricity is a fundamental concept, and Ω is a "coefficient of restraint," as it is the constant factor which determines the rate of change of the element α. Equation (21) integrated, expressed in familiar symbols, and the constant determined so that the charge is zero when the time is zero, becomes,

$$q = E\,C_1 \left(1 - e^{-\frac{t}{R\,C_1}} \right) \tag{22}$$

Equations (20) and (22) are evidently perfectly analogous, though in the first the phenomenal element, that varies, is a derived element and in the second it is a primary element.

Groups of phenomena, allied to the above might be expressed by assuming that the passive cause of equation (16) instead of being directly proportional to the characteristic element, is proportional to any function of this element. The function, α^2, is one which occurs frequently, the damping effect then being usually produced by a medium such as air.

In another important group of phenomena the effect is manifested under the following conditions: The active cause which initiated the effect has ceased to act, and the characteristic element, α, continues to exist only in virtue of the object, in which the effect is manifested, being possessed of inertia. α is then a derived element, Ω a coefficient of inertia, and equation (2) holds. Further, we have the variation of the derived element, α, produced by the simultaneous action of a passive cause, which we shall take proportional to α, and by an active cause which has its origin in the object or system itself. This active cause will be taken proportional to the primary element, ϵ. As the active cause external to the object has ceased to act, F_1 of equation (1) will be zero. The passive cause has the nature of a frictional resistance and the work that is done against it by the inertia of the system is converted into heat and finally lost to the system. It is then, as in Equation (16), equal to $-K\alpha$ and will correspond to F_2 of Equation (1). The internal active cause will act first in a direction opposite to the external active cause while it initiates the effect, and hence must be given a negative sign. As it is taken here proportional to the primary element it equals, $-K_1\,\epsilon$, and corresponds to F_3 of Equation (1). With these assumptions the group of phenomena is expressed when Equation (1) assumes the form,

$$\omega \frac{d\,\alpha}{d\,\mu} = -K\,\alpha - K_1\,\varepsilon \tag{23}$$

and this in conjunction with Equation (2) becomes,

$$\omega \frac{d^2\,\varepsilon}{d\,\mu^2} = -K \frac{d\,\varepsilon}{d\,\mu} - K_1\,\varepsilon \tag{24}$$

If Eq. (23) be differentiated in respect to d μ and $\frac{d\,\varepsilon}{d\,\mu}$ replaced by its value α, derived from Eq (2), we have

$$\omega \frac{d^2\,\alpha}{d\,\mu^2} = -\,K\,\frac{d\,\alpha}{d\,\mu} - K_1\,\alpha \qquad (25)$$

As equations (24) and (25) are of like form, they show that the primary element, ϵ, and the derived element, α, follow the same law in their variation. The integrals of these equations can therefore only differ in their arbitrary constants. The primary element will be of the nature of a space cöordinate or a quantity of electricity, while the derived element will be of the nature of a velocity or a current of electricity. The quantity, d μ, will signify an infinitesimal increment in time.

The equations (24) and (25) are recognized as symbolizing the motions of masses and electricity in a very well known group of analogous phenomena. From this group we may cite the following: The rectilinear motion of a mass attached to a spring, the motion being resisted by some frictional force which is proportional to the velocity; the motion of a pendulum bob making small swings in a medium or magnetic field that damps its motion proportionately to its velocity; the motion of a D'Arsonval galvanometer system which is magnetically damped; the movement of a liquid between two tanks joined by a pipe, the liquid standing higher in the one tank than in the other when communication between the tanks is first established; the movement of electricity between the coatings of a leyden jar, the circuit being completed through a self induction and an ohmic resistance. In the cases of motions of masses the solutions of equations (24) and (25) give space cöordinates and velocities, and in the electrical case quantity of electricity and electric current. The relations of corresponding elements of the phenomena cited might be put in evidence by a table or briefly stated in part as follows: For the pendulum, Ω, is a quantity which equals the mass of the bob, α is the angular velocity of the pendulum, ϵ the angular displacement from the vertical at any time, μ; K is a constant quantity that determines the extent of the damping which otherwise depends upon the velocity and K_1, a constant which depends upon the weight of the bob.

In the movement of a galvanometer system, Ω is the moment of

inertia of the coil, α its angular velocity, ϵ the angle through which it is displaced at any instant, μ; K is a constant which depends upon the damping power of the magnetic field, and K_1 a constant which depends upon the torsional strength of the fibre. In the electrical case, Ω, would be a coefficient of self induction, α, the instantaneous value of the current in the circuit, ϵ the quantity of electricity in the condenser, at any instant μ; K the ohmic resistance of the circuit and K_1, the reciprocal of a capacity.

The solutions of Equations (24) and (25) and the discussion of the many interesting features of the group of phenomena that they symbolize are too lengthy for the limits of this article. The curves (a), (b), (c), and (d), shown in Fig. 5, will illustrate the

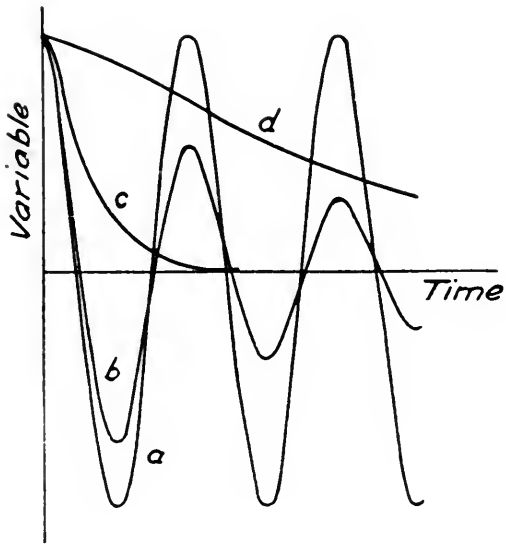


Fig. 5

four characteristic features to which the solution of the equations lead. The curve, (a) exhibits undamped oscillations, in which case the constant K is zero. This case can only, of course, be approximated by natural phenomena. The curve (b) shows a dying-out oscillation, which is the case most ordinarily encountered in nature. The curve (c) shows the primary element, ϵ, returning to a zero value by so-called aperiodic motion. In the case of a galvanometer, the system is then said to be critically damped, and the conditions are filled for the quickest possible return to zero. The curve (d) illustrates the case in which the constant K is large and the system is over-damped.

The reader interested in following in detail the developments suggested by the study of equations (24) and (25) is referred to: "Alternating Currents," by Bedell and Crehore, chapter VII, and "Instruments and Méthodes de Mesures Électrique," par H. Armagnat, chapter I.

Enough cases of the transformations and applications of Equation (1) have now been given to fully exemplify how, by proceeding to more and more extensive modifications of this equation, nearly the whole realm of physical phenomena might be symbolized. Not only will equation (1) in conjunction with equation (2) express many different groups of phenomena; it will also allow a kind of classification to be made of the groups themselves as well as of the phenomena in each group. There is one further extension of equation (1) that an account of its importance and general applicability must be mentioned but which the limits of this paper will not permit us in any way to develop. Thus, the active cause producing the effect in very many, if not most phenomena, does not cease to act after the effect has been initiated but continues to act, and is usually some function of the time. Then in equation (1) we should write $F_1 = \varphi(\mu)$, to signify that the active cause is some function of the independent variable If also we have $F_2 = -K_1 \varphi_2 (\alpha)$ and $F_3 = -K \varphi_3 (\epsilon)$, equation (1) assumes the form,—

$$\Omega \frac{d\alpha}{d\mu} = \varphi_1(\mu) - K_1 \varphi_2(\alpha) - K \varphi_3(\varepsilon) \tag{26}$$

By the relation $\alpha\, d\mu - d\epsilon = 0$, equation (26) becomes,

$$\omega \frac{d^2 \varepsilon}{d\mu^2} = \varphi_1(\mu) - K_1 \varphi_2\left(\frac{d\varepsilon}{d\mu}\right) - K \varphi_3(\varepsilon) \tag{27}$$

Equation (27) may be integrated when

$$\varphi_2\left(\frac{d\varepsilon}{d\mu}\right) = \frac{d\varepsilon}{d\mu}, \quad \varphi_3(\varepsilon) = \varepsilon$$

and, $\varphi_1(\mu) = E \sin 2\pi N \mu$ where N is the frequency, or the number of times in a unit time that $\varphi_1(\mu)$ assumes the same value. The equation now takes the familiar and important form,

$$\frac{d^2 \varepsilon}{d\mu^2} = \frac{E}{\omega} \sin 2\pi N \mu - \frac{K_1}{\omega} \frac{d\varepsilon}{d\mu} - \frac{K}{\omega} \varepsilon \tag{28}$$

If E is an electromotive force, ϵ, a quantity of electricity, Ω, a coefficient of self induction, K_1, an ohmic resistance and K the

reciprocal of a capacity the equation expresses the law of the movement of electricity in a circuit having inductance, resistance, and capacity, when a harmonic E.M.F. is applied at its terminals. The complete discussion of the solution of equation (28), so interpreted, is to be found in Bedell and Crehore's "Alternating Currents," chapter VI and following. The point to emphasize, is that the equation should not be thought of as being applicable to the electrical case only. It expresses existing relations between causes and their effects not only for electricity in a circuit but for a group of perfectly analogous phenomena. The student of mathematical physics should consider that, when he has understood these relations for one kind of phenomenon, he is equipped for seeing them in all the phenomena of a group. For example, he should find his knowledge of the equation equally applicable to a study of the movement of the system of an oscillograph, the system being partially damped, and kept in motion by the application of a periodic E.M.F. of sine wave form. Thus, if the same E.M.F. be simultaneously applied to the system of a second oscillograph, which has its system so damped as to correctly register the applied E.M.F., a certain phase difference will be shown between the traces made by the two instruments. If an electric circuit has its corresponding constants related in like manner to the constants that govern the movement of the system of the first oscillograph, then similar phase relations should maintain between E.M.F. at its terminals and the current flowing, as maintains between the traces made by the two oscillographs. Such extension of the concepts to the various phenomena of the group results most profitably in breadth of view, and depth of insight into physical relations.

Equation (1) is a general expression that may be made to symbolize the relations which exist between an effect and the cause or causes to which the effect is due. Now, the phenomenon, when expressed by the equation, is the change which occurs in an element, α, chosen to characterize the phenomenon, when a change takes place in an independent variable, μ. The equation implies that a uniform variation is taking place in the arbitrarily chosen quantity, μ, which may designate a time, a space, or other independently chosen variable. But there exist numerous geometrical relations, facts of experience, or quantities of definition that bear fixed relations to other like relations, facts, or quantities,

with which the idea of change in the elements characterizing them with time or space or other independently varying quantity, is not in any wise connected.

A consideration of such fixed relations in the above cases may often reveal illuminating analogies. Thus, if C is the circumference of a circle, D its diameter, and A its area, the fixed geometrical relation maintains that $\frac{C}{A} = \frac{4}{D}$ and, if V is the volume of a sphere of the same diameter, and S its area, then $\frac{S}{V} = \frac{6}{D}$ As these two relations are given by expressions of the same form an analogy may be said to exist between them. Another example of an analogy between geometrical relations is given by the diagram below, which explains itself.

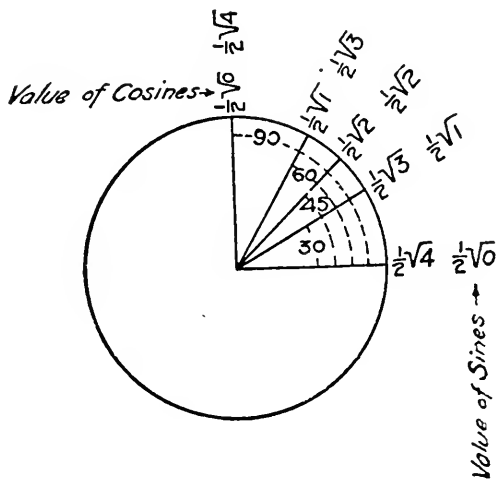


Fig. 6

The analogy consists in the values of the sines being the same as the values of the cosines, if the order in which one is read be reversed. The perception of this and similar symmetrical relations derives its value chiefly from the assistance given the memory, though it may in some cases lead to a deeper insight which will reveal unsuspected and useful relations.

As a fact of experience it is noted that two electric charges of unlike sign Q_1 and Q_2 attract each other by the law,

$$F_1 = - K_1 \frac{Q_1 Q_2}{d^2},$$

and likewise that two masses M_1 and M_2 attract each other by the same law which is given by the expression:

$$F_2 = K_2 \frac{M_1 M_2}{d^2},$$

hence it may be said that a perfect analogy exists between these two facts of observation, though no notion of a change with time is necessarily involved.

Or again, adopting the definitions that are given to the two quantities, electrostatic capacity and electrical conductance, a relation is found to exist, in any particular case, between the expressions for each which shows that a perfect analogy exists between these two quantities of definition.

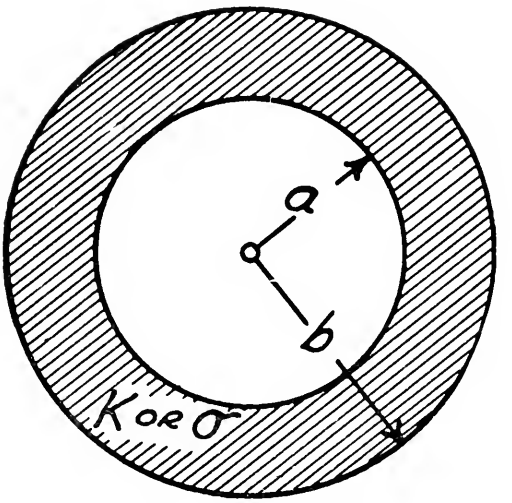


Fig. 7

An example will show this. Take two concentric spherical surfaces (Fig. 7), the inner one of radius a, and the outer one of radius b, and fill the space between them first, with a dielectric of specific inductive capacity, K. It may be easily shown (See Elements of Electricity and Magnetism, by J. J. Thomson, Ps. 86 and 136) that the expression for the capacity of the condenser so formed is,

$$C = \frac{K\,a\,b}{b - a} \tag{29}$$

Second, fill the space between them with an electrical conducting material of specific conductivity, σ, and pass current from the surface of one sphere to the surface of the other. We shall then

have as the expression for the electric conductance, or reciprocal of the resistance, of the space between the spheres.*

$$G = \frac{4 \pi \sigma a b}{b - a} \tag{30}$$

As expressions (29) and (30) are of the same form, a perfect analogy exists in this case between capacity and conductance. Indeed, it may be shown that in general the relation holds that $\frac{G}{C} = \frac{4 \pi \sigma}{K}$. The same analogy might be extended to heat conductance and other cases and many interesting deductions be drawn, but enough has been given to illustrate the character of analogies based upon geometrical relations, facts of experience, and quantities of definition. In none of these cases is the notion of change involved as an independent variable changes and hence these analogies would group themselves apart from those which are governed by equation (1) in which effects, as changes in a characteristic element, are manifested as the result of causes acting to produce them.

ANALOGIES REGARDED IN THEIR PHYSICAL ASPECTS.

The popular conception of what constitutes analogies, in physical science, is certainly not that of a likeness between the forms of different mathematical expressions, such as has been illustrated in what precedes. The analogies commonly used, and the views of them ordinarily held, are physical rather than mathematical in character. If certain physical relations or phenomena are shown to have characteristics in common with certain other, and usually more familiar, physical relations or phenomena, an analogy is said to exist between them. If a model is constructed or pictured, which in its form or movements imitates certain physical occurrences, the former is called an analogue of the latter.

In agreement with this conception of analogy we find numberless instances, in text-books, treatises, lectures and common speech, of use being made of one form of familiar phenomenon to *illustrate,* and the attempt often made to *explain,* others that are less clear or less familiar. Physicists of eminence have made

*See Ibid, p. 317.

frequent use of analogies, treated physically, and have employed mechanical models, as analogues of phenomena, to assist their imagination and to aid them to present their concepts with greater clearness. Thus, the late Lord Kelvin has said in effect:

"It appears to me that the true meaning of the question: Can we or can we not understand a particular subject in physics? is this: Can we make a mechanical model to correspond? I am never satisfied until I have been able to make a mechanical model of the object; if I can make a mechanical model I understand; as long as I am not able to make a mechanical model, I do not understand."

Faraday's lines of force conceived as elastic threads, that mutually repel transversely, is an analogue of electric and magnetic strains in the ether that has been universally used with most fruitful results. Lodge, in his "Modern Views of Electricity," has developed with much effect this analogy, as well as many other hydrodynamical and mechanical analogues. Maxwell, a master in mathematical physics, made not infrequent use of mechanical analogues and analogies. The properties of a dielectric are greatly illuminated by his mechanical illustration described in section 334, Vol. I, Electricity and Magnetism. J. J. Thomson, another analyst of the greatest power, makes frequent use of analogy, to illustrate his physical concepts. See for example his analogue of the instability of electrical equilibrium of two equal, adjacent atoms.*

The employment of such analogies as those cited, when they are not accompanied by mathematical treatment, have usually been used to assist the mind to rapidly review and grasp in outline the leading and essential features of a group of phenomena. They are not commonly employed in such cases to furnish quantitative results. But the mathematical relations between the characteristic elements of a group of physical phenomena, that are referred for clearness of illustration to a concrete analogue, may also be given. The phenomena of the group will then become joined together mathematically and *illustrated* physically. We shall now endeavor to show that, by the extensive use of analogy, in which the characteristic elements of phenomena are quantitatively related by mathematical expressions, and illustrated by

*Corpuscular Theory of Matter, p. 128, by J. J. Thomson.

concrete representations of the elements, the greatest practical ends are to be obtained. These practical ends are to be found in vividness of perception, clearness of insight, rapidity in generalization, economy of thought, and fertility in conception. It must, however, be remembered that, as the French say, "Comparaison n'est pas raison." To compare a wave motion in the ether to a mechanical model, is not to give a physical theory of such wave motion, "because it lacks that which is indeed the essence of a theory, the unity which connects in a rigorous order the laws of various groups of phenomena." But analogies and analogues, if they do not constitute physical theories, guide the mind toward framing them, and they serve beside practical ends of the greatest import. Now it is evident that the possibility of perceiving the existence of analogies between our physical concepts of nature implies that these concepts are present in the mind. This in turn, implies an acquaintance more or less intimate with phenomena themselves.

If there is familiarity with one class of phenomena, as those of the movements of matter and the conditions for its equilibrium, then a less familiar group, as the electrical phenomena, may be more quickly and easily grasped when the analogies between them become revealed either by instruction or original observation. It is an economy in mental effort, and an assistance to a well ordered memory when the corresponding elements of analogous phenomena are perceived. Thus in trying to form correct notions of the propagation of radiant energy, as light, heat, or electricity, it is helpful to refer what is analogous to the more familiar phenomena of the propagation of sound.

The ability to develop from a few primary concepts, a system of mathematical relations which are susceptible of expressing the relations of the elements of many phenomena, will not relieve one from acquiring an acquaintance with the facts, if the phenomena are to be truly understood. It is an illusive hope to suppose that because one can use physical mathematics with skill, therefore, he can know physics, without physical experience.

The above statement is thought so profoundly important that we shall attempt at some length to illustrate its force by a concrete and convincing example: For this purpose use may be made of the analogy found above, between a cylinder filled with mercury and carrying a current I, parallel to its axis, and

the same cylinder rotating on its axis with angular velocity, ω. The mathematician makes certain assumptions respecting these two cases. He mentally abstracts from the two cases the phenomena P_2 and P_3 and finds that a perfect analogy exists between the two which has been given above in equations (k) and (l) by the expressions $g_2 = -\pi I_1^2 R^2$ and

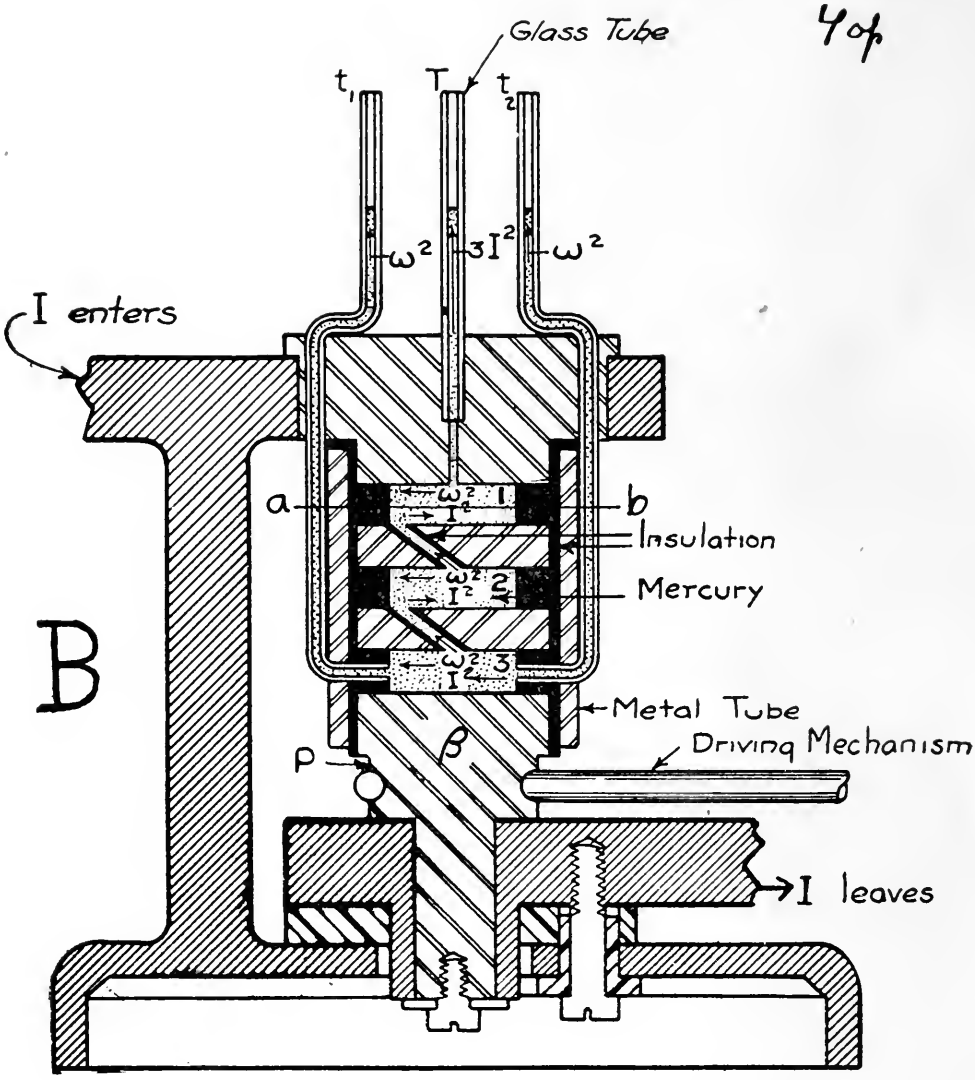
$$g_3 = \frac{\rho}{2} \omega^2 R^2.$$

These expressions tell him that in the first case, when current of density I_1, is flowing through the cylinder in the direction of its axis, that a difference in hydrostatic pressure is produced between the circumference and the axis, and that this pressure acts from the circumference toward the axis, and in the second case that, if the cylinder revolves on its axis with angular velocity, ω, a difference in hydrostatic pressure is produced between the axis and the circumference and that this pressure acts radially outward. The expressions give also the numerical values of these differences in pressure in the two cases. Now, unless further assumptions are made equations (k) and (l) give no more essential information.

Let us now see how a physicist, fully acquainted with the physical facts, could treat the problem, and by following along steps that are naturally suggested by the physical considerations of the case, arrive at interesting and, possibly useful results For this purpose let us design on paper a model that would be actually operative. Such a model is shown in Fig. 8, A and B.

B shows the model in vertical section and A, a section on the line a—b of B. The drawings have been made, complete in detail and the parts fully designated so as to save a detailed description. Now the model, as drawn, shows three compartments, which are filled with mercury. Compartment (1) at the top opens into a central tube T, and compartment (3) at the bottom opens into two tubes, t_1 and t_2, parallel to the axis of the cylinder. The entire solid portion of the cylinder is constructed of copper except the containing walls, which are made of a metal coated on the inside with an insulating enamel. The compartments (1) (2), and (2) (3) are connected by tubes having a thin lining of insulating material, and pass, as shown, from the circumference of (1) to the center of (2) and from the circumference of (2) to

4 of



Section on a-b.

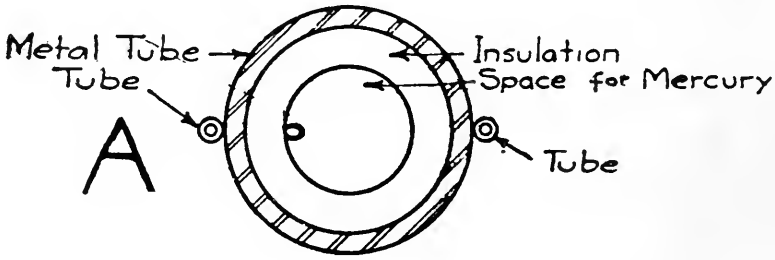


Fig. 3

the center of (3). By the pulley, P, the cylinder may be made to rotate with an angular velocity, ω. When the cylinder is stationary, or when it is in rotation, a current of density, I_1, direct or alternating, can be passed, in an axial direction, through the cylinder, passing through the mercury in the compartments and through the copper partitions which separate them, except where the small connecting tubes go through them.

First suppose the cylinder is stationary and that a current of I_1 amperes per square centimeter is passed through it. The equation (k) tells us that a lower hydrostatic pressure will exist at the circumference than exists at the axis, and we should therefore expect the mercury, as in fact it would, to rise in the tube, T, and depress in the tubes, t_1 and t_2.

But here is what the equation does not tell us, and which we must be led to find out by considering the problem physically, namely, that the pressure difference produced in compartment (3) is added to the pressure difference in compartment (2) and this in turn to that in compartment (1). Hence the mercury will rise three times as high in the tube, T, as the equation (k) would indicate.

Second, suppose the current is not passing, but that the cylinder is rotated with an angular velocity, ω. Equation (l) tells us that the mercury will lower in tube T, and rise in the tubes t_1 and t_2. But, by physically conceiving this case, we see that no more than one compartment can be effective in producing a pressure-difference. This is because the pressures set up are hydrostatic, and however large or small we make the diameters of the slanting tubes connecting the different compartments, the centrifugal force acts in these tubes, as well as in the compartments, thus preventing the pressure difference of one compartment being added to that of an adjacent compartment.

In this respect then, namely, of the pressures being added in the one case and not in the other, equations (k) and (l) are not analogous and on this point suggest no information. We are taught, however, by the physics of this case that we must introduce in the first instance a factor, N, that expresses the number of compartments that are joined by the slanting tubes in series. Equation (k) then becomes,

$$g_2 = -\pi N I_1^2 R^2 \qquad (31)$$

Or if we write I for the total current passing through the cylinder, we have, since $I = \pi R^2 I_1$

$$g_2 = -\frac{N I^2}{\pi R^2} \tag{32}$$

We are now led to note that by applying the right current and the right angular velocity, the oppositely acting forces produced by the current and by the rotation may be made to balance. The balance will be indicated by the mercury in the tube, T, showing no change of level when current is passing and when the cylinder is rotating.

By writing the equation denoting the condition of balance, *i. e.*,

$$\frac{\rho}{2} R^2 \omega^2 - \frac{N I^2}{\pi R^2} = 0 \tag{33}$$

we obtain as the value of the current

$$I = R^2 \omega \sqrt{\frac{\pi \rho}{2 N}} \tag{34}$$

It is also possible to obtain the value of the current independently of the radius, R, of the cylinder. To do this, stop the rotation but keep the current unchanged. The mercury in the tube, T, will then rise a certain height, h, above the level of the mercury in tubes t_1 and t_2. If g is the intensity of gravity, we shall have,

$$h = \frac{g_2}{g \rho} = \frac{N I^2}{g \rho \pi R^2} \tag{35}$$

Now, R_2, may be eliminated from equations (34) and (35) giving

$$I = \frac{h g}{\omega} \sqrt{\frac{2 \pi \rho}{N}} \tag{36}$$

This unusual method of obtaining in absolute measure the value of a direct or an alternating current in terms of a height, the intensity of gravity, an angular velocity and a density, was led up to very naturally by considering a particular case in its physical aspects and with a knowledge of the physical facts involved. The mathematician attempting to build up a system of analogies. by starting with a few fundamental concepts and from these developing systems of corresponding equations would scarcely arrive at a result like the above. The physicist, however, fully ac-

quainted with physical facts and using his mathematics as a tool and not as a guide, is very naturally conducted by the suggestiveness of the object studied to new analogies and new points of view. Moreover, his acquaintance with physical facts teaches him to interpret his equations of analogous phenomena at their true value as expressive of real physical law. Thus, in referring to equations (24) and (25) a well informed physicist would interpret these equations, when applied to the electrical case of electricity oscillating in a circuit of capacity, inductance, and ohmic resistance, as very approximate only. He would know what the mathematical view, alone, would not, and in fact did not, teach, that the resistance of the circuit is a function of the frequency of the oscillation, and may not, therefore, as assumed in the equations, be treated as a constant of the circuit.

In tracing and building up analogies by conceiving phenomena physically and by forming mental images of concrete illustrative examples of the phenomena, the *like elements* common to the phenomena of a group, and the *unlike elements* not common to the phenomena of the group, are both revealed. It is the like elements that determine the analogies if they exist, and by these elements the phenomena are classified and grouped together. But it is the perception of the unlike elements that leads to new points of view, to new relations and to the forming of new analogies. The perception of the contrast between the like and the unlike will lead to inquiry as to wherein the difference lies. Thus experiment and further investigation are suggested and the path is opened to enlargement of view and possible discovery. In expressing the relations between the elements of phenomena by mathematical equations, only those elements are dealt with which were mentally abstracted in the original assumptions. If then mental images of concrete cases are not before the view, no new elements will come into the combinations formed; new points of view will not be obtained, and invention is unlikely, and discovery is impossible to follow. The mathematician who depends upon his symbols to give him new results is very like a child with a kaleidoscope. The child following his fancy may take from a pile of bits of colored glass a number of pieces that attract him. If then he places them in his kaleidoscope he thinks perhaps to find something new by watching the endless combinations of symmetrical forms. But if he did not chance to select red, or green, then these colors

will never appear to him, however long he turns the combinations. To get red or green he must return to the pile of colored glasses, the only source of new matter. So the mathematician who symbolizes his original assumptions, and then neglects the source from whence they come, will never find anything new however long he studies their fascinating combinations. To find what is new, and indeed, to increase the possibility of the combinations, he, too, must return to nature.

When two or more objects or phenomena are presented, in concrete form, it is almost always possible to find an analogy between them in respect to some of their features or some of the elements that attach to them. Now these elements, taken as a basis of comparison, may be merely accidental elements, as of form, color, temperature, and the like, and not elements that are characteristic of the object or phenomenon; that is, elements that must be considered in framing an exact definition of the object or phenomenon. Where analogies are traced that depend upon elements that accidentally attach to the particular objects in view, they are lacking in value from the standpoint of science. As the tracing of accidental and unexpected relations between non-essential features belonging to objects, often gives pleasure, and new points of view, it has a legitimately recognized value for literature. Thus to say,—

> "The quality of mercy is not strain'd,
> It droppeth as the gentle rain from Heaven,
> Upon the place beneath;"

is to trace an analogy that has fine merit in literature but is worthless in science. Such an analogy cannot help to extend or clarify scientific concepts. In fact, in the early development of science, the use of such loose analogies did great harm. They draw the attention from elements that are essential in defining objects, to elements of a non-essential and accidental character.

In referring phenomena to a phenomenon with which there is a perfect analogy, in the true scientific sense, the phenomenon selected as the standard phenomenon, so to speak, should be one capable of very precise definition, and one that is as far as possible universally and instinctively comprehended.

In attempting to unify physics and to arrange its varied phenomena in some kind of order and to trace among these phenom-

ena as many likenesses and connecting links as possible it should be enquired what classes of phenomena are the most universally and instinctively known. These phenomena will be those best suited to serve as prototypes of the different groups of phenomena. The phenomena in question are undoubtedly those of the equilibrium and the movements of ordinary solid matter. In other words the phenomena of mechanics are those that are most precisely defined, the best known formally as well as instinctively, and may best serve as prototypes of all physical phenomena. We are thus led to briefly examine the rôle played by mechanics in the scientific analogies that exist among physical phenomena.

THE RÔLE OF MECHANICS.

In accordance with what we have shown in the beginning of this paper it is evident that, if any phenomenon can be expressed by an equation of the same form as one that expresses a mechanical phenomenon—that is the relation between the movements of a material system and the forces that act upon it,—the two are analogous. Throughout the later developments of physical science, puissant attempts have been made to *explain* all physical phenomena, including those of heat, on a purely mechanical basis. But even with the assumptions that have been made by Hertz and others of the existence of "concealed masses, concealed motions, and concealed cöordinates,"* this attempt appears to the writer little likely to become successful.† But, if we limit the use of the movements of mechanical models and systems, to *illustrate* all the features of phenomena that are capable of interpretation and of being understood, then we may turn to mechanics as furnishing models par excellence of all physical phenomena. Mechanics, in this interpretation, in addition to its fundamental character, may serve to play a most essential rôle by associating together and cöordinating in the mind the whole domain of physical manifestations. From infancy, and indeed by phylogenic experiences from an unknown past man has acquired an instinctive and unerr-

*The Principles of Mechanics by Hertz, Section 595, and Introduction, pages 25 and 26.

†Consult on this important matter L'Evolution de la Mécanique, Chap. XV, par P. Duhem.

ing perception of mechanical laws. If he cannot formulate them he can always adjust himself to them. In the domain of light, of sound, and especially of electricity, it is not so. The phenomena must here be learned under specially arranged conditions. When, therefore, one begins to formulate his concepts of the invisible, and intangible manifestations of electricity or of the wave motions of radiant energy, it is a powerful and proper instinct that leads him to visualize in terms of mechanical things he knows, the new phenomena that he strives to comprehend. By his mechanical concepts it becomes possible for him to give a concrete aspect to what otherwise may remain a vague abstraction. From this point of view, the mental or actual construction of mechanical models, that are capable of movements which are related to time and to each other in the same way that the variations in the variable elements of phenomena, considered non-mechanical, are related, serve an important purpose and satisfy an intellectual necessity. Even a mind that is capable of powerful abstraction must lay hold of something. It may be conventional graphical representations, or it may be mathematical symbols, and, it is true, many will contend that these last will serve as well as the more concrete and specialized mechanical models. These would reason from an individual case as follows: The sinusoidal feature of an alternating current may be represented in many, if not all, of its essentials, by a model. This model may consist of a long row of small white balls attached to the ends of vertical wires that by their properly timed up and down movements cause the balls to show a progressive wave motion of sinusoidal character. Now, it may be truly said, that this model is as unlike the electricity that moves as would be a system of lines drawn on paper to represent the wave motion. The model by its movement represents progressive variations, with the time, like the variations in the elements of the phenomenon that it represents. But systems of lines on paper may be made equally to show these variations. It is only necessary to represent the successive stages of the motion and make use of a stroboscopic apparatus to make the lines do exactly as well as the model. But why not write the equation,

$$y = I \sin (\varphi + 2 \pi N t).$$

Does it not tell us exactly as much as the model or the diagrams,

and is it any more unlike electricity than balls on wires and lines on paper?

As neither model nor lines, or equation *explain* the phenomenon, but only represent the variations in those elements of the phenomenon that one has chosen to fasten his attention upon, why not use the equation as the most compact, cheapest, and manageable symbol of the reality? Nevertheless, we believe there is a great value in the model, though we would not contend that it shall *replace* the equation. We do contend that its value is such that it should *supplement* the equation and for these reasons: In viewing a model or a mental image of one, all the essential relations, respecting the phenomenon, that it expresses, can be taken in, so to speak, at a glance, and viewed in their entirety. In consequence of this a vivid and lasting impression is made upon the memory, which the mind often will have occasion to recall when analogous phenomena to those represented are brought under contemplation. Again, the model makes its strong appeal to the universal, instinctive knowledge of our race, while the equation appeals to a highly specialized knowledge that many excellent minds never acquire. But most important of all is the suggestive character of the model. The equation was formed out of elements deliberately abstracted from the phenomenon, and once having been formulated, all other possible elements, that might have been considered, are henceforth totally neglected and forgotten. The equation can give all possible combinations of the elements originally abstracted and that is all. Not so with the model. In observing its form and in noting its movements, new characteristics other than those first contemplated, are seen, and these new elements being noted in the model, the mind with great naturalness enquires if these new elements may not also belong to that which the model represents in other respects. Thus further examination is suggested, and invention and fertility follow.

We should, however, not assume other values for our models and our analogies than one of a purely practical character. The tracing of the analogies and the concrete representations of them has not given us a law or formulated a theory. In other words, it has not *explained* the phenomena in a broad sense. But this practical gain is most important. The vast majority of our judgments passed upon the relations that maintain between causes and their effects when presented to us, must be made not by criti-

cal analysis, but by referring the physical event in question to some analogous event with which the mind has already been familiarized. The greater our possession of true mental images, and the greater the number of these images that are joined together in natural analogous relations, the more swift and unerring are sure to be our judgments of new phenomenal relations. Until, however, these judgments are given the precise setting of numerical relations, they must remain qualitative rather than quantitative. And herein lies the necessity in the exact sciences, of being able to formulate in the precise language of mathematics, the relations between the phenomenal elements that we select for consideration. The physicist, with strongly developed visualizing power, and a broad view of analogous relations, is not therefore free to depart from the employment of mathematics and the methods that it teaches. Nor, on the other hand, may we hope to wholly rely on this powerful instrument of thought, if we would frame concepts of the external world that may fairly represent it.

If we now return to the developments which we made of equation (1) above, and consider the innumerable further extensions that a mathematician might make of it, we may see how barren would be the results obtained for increasing our knowledge of nature, unless parallel with these developments, a physical illustration and a physical interpretation be carried along.

ASSOCIATIVE PHYSICS.

The science of physics is studied to know nature, to instruct others, and to serve the other sciences and engineering toward practical developments. One or all of these ends may be the objects of its pursuit, but we may enquire if the same methods in its study are not called for in any case? Now it seems evident, that with any of these ends in view, it is equally important to the student of the science to observe the best mental economy whereby his powers may be conserved to compass as far as possible the vast extent of his subject, to acquire the most broad and broadening view, that the study may serve as a culture to his mind and enlarge instead of narrow his general scope, and finally, to furnish him with a strong command of the largest possible number of essential facts. All these demands may best be met,

for whatever ends his physical science is pursued, if he observes a fundamental psychological law of this character: that new knowledge is only acquired by association of the ideas formed through new perceptions with the concepts that are already firmly possessed. As ideas are associated, so is a mind constituted. In one mind, bound with the iron chain of habit, the ideas are of a mosaic character. The characteristic elements and the natural connections of phenomena and objects are unnoted because the accidental and not the fundamental elements have been habitually fastened upon. But in a better type of mind, the associations between the ideas belong to those characteristic elements that define objects and phenomena. The principles and the laws that govern large groups of phenomena are mentally associated in a harmonious arrangement. When a new perception comes, it finds forthwith its orderly setting among extensively connected concepts already possessed. The true value and relationship of the new perception is quickly and intuitively estimated and the remembrance of the perception only retained if it is worth while. If in this mind the new perception is seen to have no natural connection with what is already possessed, intense curiosity is immediately aroused and investigation is started; and so come discoveries.

To the first type of mind a multitude of particulars, that lack logical connection, must burden and overwhelm the most vigorous intellect, if it tries to gain a grasp of the vast domain of natural phenomena.

To the second type of mind, made by habit, wisely selective in its judgments and memory, the essentials only, that characterize large groups of particulars, are given consideration. This mind, with perhaps less native intellectual vigor than the other, can grasp a far larger universe and better impart the knowledge of it to others, and make of this knowledge more extensive use for practical ends.

To help toward the formation of such a well ordered and economically working mind physical science should be viewed, taught and used as an association of facts, laws, principles, and manifestations that appear similarly and indifferently in all its, at present, artificially separated branches.

For the most part, modern general treatises on physics start out with an exposition of the principles of mechanics, then fol-

iew treatments of the properties of matter, sound, light, static and dynamical electricity, and magnetism, followed perhaps with some added chapters upon radiant electric energy, Röentgen and Becquerel rays and the recent discoveries in radio-activity. Little or nothing is taught respecting the intimate relationship and the profound analogies between all these subjects. Seldom is a word spoken concerning the bearing of all the isolated facts and principles exposed, upon the intellectual and practical needs of man. The profoundly important philosophy of the science is entirely omitted. Each subject is set forth to be learned and, alas, memorized, by the student as so many distinct and separate branches of physical science. Perchance in riper years, if the student pursues his studies, and after the formal and piece-meal knowledge that he early acquired is forgotten, he will come to realize, and delight in the thought, that a true and broad physics is not sets of equations, nor measurements of lengths, volumes, and curvatures, but a philosophy that applies to human life. He will see that its subject matter reaches to the confines of the universe and has relationship with every interest known to man. He will perceive that its grand laws and principles simply express in orderly form our most intimate knowledge of the world we live in. And he will see, too, that after all, "the most sublime scientific knowledge, in the last analysis, has no other foundation than common sense."

INCREASING USE OF STORAGE BATTERIES.

It is predicted by the *Electrical World* that the use of storage batteries will increase greatly in the next few years. It cites the belief of many engineers that the steam turbine marks only a transition period in prime movers, which must give way to the internal combustion engine because of the superior economy of the latter. The gas engine has no overload capacity; it operates best when delivering a steady amount of power, and is liable to give trouble when worked on light loads. The storage battery affords the required flexibility in respect to variations in the external load while maintaining a constant load on the generating equipment; as one writer puts it, "the storage battery is the natural consort of the gas engine." An extended use of gas engines for driving electric generators will undoubtedly be attended by a corresponding increase in storage battery work.

THE FRANKLIN INSTITUTE.

The Equipment of Farms and Country Houses With Electricity.

By Putnam A. Bates, New York, N. Y.

The difficulty of obtaining satisfactory farm hands and of providing for them makes the machine, which can be substituted for manual labor, a decided advantage to the land owner. This fact, together with the greatly improved quality of illumination and convenience which electricity gives, is causing a growing demand for a reliable and reasonably economical source of electrical energy with which to supply both light and power on the larger country estates and farms.

The advantages of convenience and cleanliness with the use of electricity are pretty well known and appreciated, but the means by which electric currents may be obtained, economically, and how this form of energy may be applied to bring about sufficiently better returns to justify the installation of an isolated plant to produce it, are points not so generally understood.

A brief resume, therefore, of what can be done and what has been done in this direction may serve of some interest to those who have chosen farming for their pleasure or their livelihood.

Within the last few years the small internal combustion engine and the electric storage battery for stationary service have been so much improved and simplified as to cause them to compare very favorably with the better known types of power producing apparatus in reliability of operation and in first cost. The extreme simplicity of both this type of engine and of the storage battery, together with the very great economy in fuel consumption of these engines, the low price of fuel, and the efficiency of the battery as a device for storing the energy and delivering it in the form of electric current when needed and in the quantity required, result in a very low operating cost.

The advent of tax-free alcohol in the field of available fuels for use in internal combustion engines is being watched with interest by those concerned in this problem, and while it is too early as yet to make any predictions, this fuel has already given promise of, in time, becoming a strong competitor of kerosene and gasolene in this field.

There is still another promising source of power for these small plants which is too often overlooked. That is, the small water powers, which are scattered through the country, most of which could be easily developed at small expense, and many of which have already been developed for commercial purposes, abandoned because of changed conditions, and require simply the addition of the electrical apparatus to make them valuable sources of energy.

Such a water power plant could frequently be made to serve a group of users of electric current at very small first cost for each individual, and at an operating cost per kilowatt hour which would be almost nil.

It is, therefore, evident that the means are at hand by which those not reached by a reliable and low-priced electric service may still avail themselves of the electric current and obtain the many conveniences which it contributes, at a cost which should seldom exceed that of an equivalent service from a public service electric plant at the rates ordinarily prevailing, for such service, throughout the country.

It must not be lost sight of, however, that very much depends upon the design of these small isolated plants and the manner in which they meet the requirements of the equipment which they are intended to supply.

This suitability to the requirements is even more important in these small plants, where the load conditions are practically fixed, than in the much larger public service plants, where the load is much more elastic and may, to a considerable extent at least, be controlled and shaped to meet the capabilities of the power plant equipment by the selling organization of the owners. Many small power plants have been abandoned as unsatisfactory and extravagant, or as luxuries of questionable worth, after a short period of operation, or are being run at excessive cost and with little satisfaction merely because the apparatus is there and no other source of electrical energy is at hand, for no other reason than that the

apparatus installed is not of the type or quality required for satisfactory generation of electrical energy or that the capacities of the various units of the plant equipment are not well suited to each other or to the load conditions to be met.

For this reason it is very inadvisable to decide this question in an offhand manner, or, after having decided upon the installation of a power plant, to leave the details of its equipment to the contractor, for, no matter how honest he may be in his dealings with the purchaser, the planning of such work is out of his line, and he cannot afford to give it the time which it requires, nor has he the facilities for doing engineering work of this nature.

That electric light is much cleaner and more convenient than kerosene lamps is, of course, admitted by all. It is also admitted that a kerosene lamp has too many of the characteristics of a stove to make it pleasant company on a warm summer evening. When it comes to a matter of dollars and cents, there is a general belief that kerosene is considered cheaper, as a source of illumination. This is too often allowed to go uncontradicted, and many times even electric light men will accept this view without taking the trouble to go into a close investigation of the matter.

To thoroughly compare the cost of the two, it is well to start with the assumption that the house in question is to be lighted electrically and calculate the cost of lighting on this basis. We know how much current each lamp will require per hour and the rate at which the current will be purchased, therefore, the rest of this part of the calculation is simple. Next, we must assume that we will install an oil lamp of candle power equal to that of the electric lamp in each place that had been selected for an incandescent lamp. With this same number of kerosene lamps burning the same number of hours will give a figure, for cost of oil plus cost-of keep-up in the form of new chimneys, wicks, time of trimming, filling, etc., which will total quite as much as the cost of the electric current, particularly so, as with the oil lamp it is necessary to kalsomine or decorate about every season in order to keep the rooms in a clean condition. This latter cost is necessarily large, and, usually, otherwise unnecessary and should be charged against the kerosene lamp, as a source of illumination.

It is, however, in the application of electricity to labor saving devices, that the greatest gain is to be derived on the farm or country place; and, unless the number of lights to be used each

night averages twenty-five or more throughout the year, it would not pay to install a generating plant for lighting only, without it be confined to the simplest possible equipment. This might consist of an engine and dynamo, but such an equipment could not be conveniently and economically operated to give twenty-four hour service.

There has recently been some activity in the direction of developing the primary battery for commercial use in the especially small isolated places where lighting by electricity is much desired and only a small outlay in first cost will be permitted. The writer has, himself, spent about two years in studying the primary battery situation to determine the feasibility and practicability of utilizing for private isolated plant work, this seemingly convenient and direct method of generating current. The present state of the art, however, provides us only with forms of apparatus very much enveloped in limitations and to such an extent that the electric generating batteries commercially offered for lighting or power service are more suitable for the experimenter than the user who wishes to confine himself to standard articles of equipment.

It is often said, and quite truly, too, that as a class the farmer is more independent and well-to-do than men of any other walk in life. The reason for this is that he is surrounded with natural resources which make him a producer; and, if he is only industrious, his conditions are bound to improve. What he needs, therefore, is merely the sign post to show him the way to obtain the means by which he may increase the returns from his labors, either in greater output or in higher prices.

Each year our farm produce and crops are being more scientifically dealt with and the benefit is reflected in the annual valuation reports.

Apropos of this condition I quote from a report sent out last August by a N. Y. State Farmers' Club, which met and resolved that: "Within a few years there has been a strong drift from city to country; that farm lands are not depreciating in value, but are slowly rising in price; that the farmers receive from one-fourth to one-third more for all produce than they did ten or fifteen years ago, and that there are no abandoned farms in the State."

The agriculturist's position, therefore, is no different from that

of the manufacturer, who has to first supply himself with the machines and tools of the most approved pattern before he is ready to turn out the finished product with which he expects to meet competition.

To infer that the farmer is not financially able to properly equip himself with the most approved and scientific devices for the successful and economical operation of his industry would be as far from the truth as anything we could say.

With lands slowly rising in price the farmer is not offering bad security, if he borrows against his property, in order to equip his farm so that he can produce as much as his neighbor, but at a lower cost, or more than his neighbor, at the same cost and obtain better prices through improved quality of produce.

To give some idea what may be accomplished, I will describe to you the equipment of a private electric generating plant, which one of my clients has at his farm on Long Island, and which serves as a fair example of a plant that would meet the needs of many similar establishments, provided, of course, due allowance be made one way or the other to take care of local conditions.

This farm, which consists in all of about three hundred acres, a portion of which is salt marsh land, not permitting of cultivation, was for years allowed to grow wild, and it was not until about two and a half years ago that the present owner bought the property, and proceeded to develop it along modern lines.

The house was rebuilt, and provided with modern plumbing and heating, and was wired for electric lights throughout. This latter feature, of course, required that connection be made to some source of electric current supply.

The number of incandescent lamps, with which the house is equipped, is about one hundred and sixty, and besides these it was desired by the owner that electricity be provided for light power work in the house and in the farm barn. In the former a motor was installed for operating an organ blower, also one for a small lathe and polishing wheel.

All the machines which the owner had in his barn, with one or two exceptions, were old, but were easily cleaned up, and by supplying a few missing parts, etc., they were arranged for belt drive from a countershaft.

They consisted of a feed grinder, root cutter, fodder cutter, fanning mill, grind stone, circular saw, corn sheller, a small drill

press and a horse clipper. A very nice arrangement of these was made by grouping, so that they can all be driven from one countershaft, which in turn is belt driven by a 3 H. P. motor.

The fact that no two of the larger of these machines are apt to be needed at the same time makes it possible for so many to be taken care of with this one motor.

The barns consist of a number of buildings grouped in "L" shape, the building containing the above mentioned farm machinery being at one end and a small carriage shed at the other. The intermediate buildings are: the creamery, carriage house, horse stable, wagon sheds, etc. The cow barns and poultry houses are separate from the other buildings, and tend to close in the quadrangle.

The house is about six hundred and thirty-five feet from the nearest farm building.

The distance from the center of the group of farm buildings to the entrance to the place, or the shortest distance to the nearest highway, along which the Public Lighting Company's wires are located, is 1900 feet.

The problem, therefore, which had to be solved was: whether the rate at which the Public Lighting Company would supply current, plus the interest on the cost of running a private feeder line this 1900 feet, would make an annual expense greater or less than the yearly cost of operation of a private generating plant of sufficient capacity to take care of the electrical equipment described above, and also a few other useful devices, which at once suggested themselves, to which the electric current is particularly adapted as a source of energy.

A study of the lighting installation planned for this particular residence, with its main stable and farm buildings, indicated a probable average lamp load on ordinary evenings of sixty-four lamps in use for four hours, and on special evenings a maximum load of possibly twice this amount.

To supply the necessary electric current for this lighting load, together with that for the three or four power motors, which the owner had planned for, would have involved a yearly cost for current alone, if taken from local lighting company, of between $1000 and $1100, and besides this, the interest on the cost of installing the private feeders to connect with the Lighting Company's mains, also the cost of maintaining this feeder line.

By installing a private plant, the cost of which in this case amounted to about $3500, the yearly cost of operation figured out approximately $670. This being made up of fuel, lubricating oil, waste and minor repairs, $250, and interest and depreciation at 12%, or $420.

As this plant was so planned and installed that its operation should be practically automatic, no charge is included for attendance. The person looking after the plant need not necessarily be a skilled mechanic, and his duties would not be much more than to each day start up the engine and generator for either the direct service or for charging a storage battery with reserve energy.

The time for starting and the length of the run being predetermined, the attendant is free to attend to other duties most of the time.

It will be seen from the above that the cost of generating the electric current with this private plant is less than two-thirds the amount which the owner would have had to pay the Lighting Company.

Aside from the actual money saved there are sufficient practical advantages to justify a similar decision in favor of the private plant in most country estates when the demands for electric current approach those in this case.

This is particularly true where the demand for power amounts to considerable, for it is very seldom that the service of a public lighting company, to country districts, provides other than alternating current. With the alternating current the methods by which motor speeds are controlled are not so flexible as those for the direct current and, consequently, it is not possible to regulate and to govern the speed at which the various mechanical devices shall be operated. This feature is often quite an important one, as for instance in pumping water, separating cream, grinding feed, etc. With a private plant the generating apparatus can generally be placed in a location which is approximately central with respect to the buildings to which it is to supply current, and the length of the feeders, as a rule, is not so great as to make distribution at low tension prohibitive.

Before passing to some of the uses to which electricity may be easily and profitably applied in the field of the agriculturist, I will describe, briefly, the equipment of the plant, which I have used as an illustration. This may assist some of those present to obtain a

better idea of what such a plant consists, and how satisfactory results may be reached without the outlay of a large sum of money.

The building which was selected for the power plant is that forming the westerly end of the "L" formed by the group of farm buildings. While this location is about 250 ft. from the building containing the farm machinery and the creamery, adjoining, it is the nearest farm building to the residence; being, as mentioned before, about 635 ft. distant.

This location put the site for the power plant about central, with respect to the load to be carried, and it permitted of transforming an unused carriage shed into a power plant at a trifling cost by the substitution of a concrete floor for the old wooden one, and the erection of a three-way partition dividing the original floor space into three.

The building is a one story structure, approximately 20 ft. wide and 30 ft. long, and when partitioned it gave a front room of 15 ft. by 20 ft. to be used as an automobile garage and supply storage, and the partition at right angles to this, gave, in the rear, a room of 10 ft. by 15 ft. for engine and generator, and one of like dimensions for a storage battery.

The only additional work involved in transforming this building from an abandoned shed, such as is to be found in almost any group of farm buildings, was to bring into the building a water pipe connection, make the concrete floor of the engine room four feet deep under the engine and generator and the addition of an air-vent or ventilator over the battery room.

A study of the probable conditions of load, which this plant would have to meet, indicated that the most economical method, both in first cost and operating expense of supplying current for the average load, would be to operate an internal combustion engine generating set during the evening and feed the lights directly from the dynamo. In order, however, to take care of the motor load, which would have to be met at irregular intervals, and to provide a continuous source of supply during the entire twenty-four hours of the day and night, which is of course very desirable, and to provide an auxiliary for the generating set to help carry the load upon special evenings, or the entire load in case of the generating set being shut down for any cause, a storage battery of suitable capacity was installed.

The engine selected was of the internal combustion type, using

crude petroleum, or some of its products readily obtained in the open market in barrel lots. The full load capacity of the engine is ten horse power, and that of the electric generator is five kilowatts at 125 volts, the current of course being direct. These two machines were directly connected, the armature of the generator being mounted on an extension of the shaft of the engine and both mounted on one cast iron base.

The capacity of the storage battery installed in this plant is 288 ampere hours, or 36 amperes for 8 hours, which is sufficient to take care of all the day load, the night load from bed time until morning, and provide a constant reserve source of energy at all times.

As I have stated in the beginning of this paper, many isolated plants have been considered unsuccessful owing to an ill-proportioning of the apparatus. In a large percentage of these failures the trouble has been due to the selection of too small a battery and too large a generating set. The result being that the battery is always in need of being charged and the generating set represents an unnecessarily large first cost, and, as it is too large for practically all load conditions, it has to operate with a low degree of efficiency.

This condition is avoided by installing a storage battery of sufficient capacity, when fully charged, to supply all ordinary demands for current for a period of two to three days, and a dynamo of suitable size for charging the battery at its normal rate.

The combined output of the battery and dynamo must, of course, be sufficient to supply the maximum load that the plant will ever have to carry.

A power plant of this general description requires absolutely no attention other than an occasional brief inspection, except when it becomes necessary to charge the battery or when there is a special demand for current.

The operation of charging the battery requires only occasional attendance upon the plant, and while this must be given regularly, a very large proportion of the attendant's time may be put in at his regular duties while the battery is charging. The location of the power plant frequently has much to do with economy of the attendant's time in this connection.

The engine used in a plant of this description should be of a type especially suited to the driving of electrical machinery. It

is highly important that its speed should show very little variation under conditions of changing load and throughout the cycle of operation of the engine. In no other way can satisfactory electrical service be obtained.

The engine should also, it is needless to say, be economical in fuel consumption and in the use of lubricating oil and other necessary supplies, and should be as nearly absolutely reliable in its operation as is possible.

The dynamo for such a plant may be either of the ordinary compound wound type, or it may be of the variable voltage type, with compound field winding, capable of operating directly upon the line as a compound wound machine, or of operating as a shunt wound machine when used for charging the battery, delivering current to the battery, at any required voltage up to forty per cent. above normal. The former is slightly simpler, as far as the dynamo is concerned, and gives better regulation of voltage, but it requires that a small motor dynamo or booster set be provided for raising the voltage for battery charging; whereas, the latter method eliminates the expense of a booster without going to the other alternative of dividing the battery and charging through a resistance, which is an inefficient method of operation, and requires either a larger dynamo and engine, or a doubling up of the time necessary for charging.

A very vital point to be considered in connection with any plant operating a storage battery is the regulation of the voltage at which the current supplied by the battery on discharge is delivered to the line. Some means must be provided by which this voltage will be kept constant or cause to vary slightly in proportion to the load carried, under all conditions of loading and wholly independent of the decrease in the voltage of the battery itself as its charge is converted into electrical energy and withdrawn.

There are a number of ways in which this may be done, but, for a plant of this description, where a minimum of attention is essential, and yet where the voltage regulation must be as nearly perfect as it is possible to have it, the most satisfactory method of regulating the voltage is by means of a variable resistance placed in series with the battery and automatically operated through the medium of a relay connected across the line.

This relay may be differentially wound so as to produce an

over-compounding effect and in this way may overcome the loss in pressure between the switchboard and the lamps, and also allow of the operation of the battery and dynamo in multiple, in the same manner that two compound wound generators may be operated.

Such a voltage regulator can be obtained at a cost entirely commensurate with that of other methods of controlling the voltage, and the results obtained, in a plant of this nature, are far more satisfactory.

On farms and country places of considerable size, it is usual to have what is ordinarily known as a handy man, who is more or less familiar with the machinery, its care and operation. Such a man is almost indispensable for the care and operation of automobiles, launches, labor-saving machinery, the heating apparatus in the residence, greenhouses and other buildings, and the general up-keep of the various mechanical and electrical devices.

Such a man may readily, and to great advantage, be placed in charge of the care and operation of the power plant, as this will require so little attention as not materially to increase his duties.

Water power that can be relied upon for sufficient energy, of course, makes the least expensive source of power; but, if a suitable water power is not available, an engine of some kind must be provided. A consideration of the two general classes, namely: those driven by steam and those in which the fuel is burned within the engine cylinder will usually result in a choice of one of the latter type, as with the former the necessity for a high pressure boiler, with its smoke stack, adds considerably to the cost of the equipment, and the power house building and the greater complication of the steam plant requires a greater expenditure for labor than is necessary for a plant in which the prime mover is an internal combustion engine.

An exception to this might be, of course, in large dairy farms, or other places where it is of importance that there shall always be plenty of real hot water on hand for cleaning purposes.

In deciding upon the particular kind of internal combustion engine to install, that is, whether it shall operate on producer gas, natural gas, or illuminating gas, or gasolene, kerosene, or crude petroleum, a conclusion should be reached only after a careful consideration of duration of the load, the relative costs of the

various fuels at the point where the plant will be located, and the possible fire hazard of one or another, as well as the relative cost of the various types of engines with their auxiliary apparatus.

The possibility of a disproportionate increase in the cost of any of the fuels considered, or of its becoming difficult or impossible to obtain some one or more of these fuels in the future, should also be carefully considered.

After a power plant has once been installed there are many ways in which it may be used to great advantage, that are perhaps not so fully appreciated by the prospective purchaser, as they are

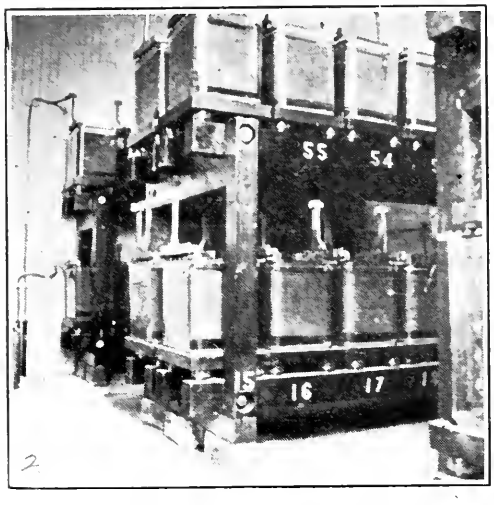


Fig. 1. A direct-connected dynamo and a kerosene oil engine. This generating unit is the one described earlier in this paper in reference to the private plant on Long Island.

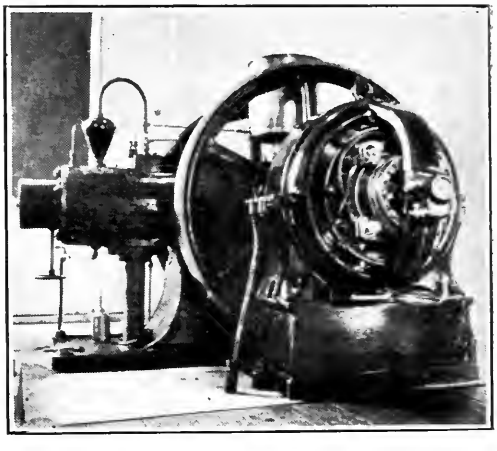


Fig. 2. Electric storage battery, same plant.

by the owner of one of these little plants. It is a fact that the largest items of operating cost in a small plant, designed principally to take care of the evening lighting, are those of interest upon the original investment, and depreciation in value of the equipment as it ages, the cost of fuel and attendance being, comparatively, small items. These facts make it apparent that such current as is used at other times than during the evening, and, therefore, without necessitating any additional investment or greater depreciation charge, may be generated at very small cost.

It is, therefore, possible to add greatly to the conveniences upon a country place equipped with an electric plant, by the installation of electrically operated devices of one kind and another, which would be out of the question if current for their operation had to

be purchased at the prevailing rates for public electrical supply.

Turning to the slides, which I have prepared to illustrate some of the points mentioned this evening, we will see:

This equipment, at the time I last tested it, separated the cream of sixty quarts of milk in thirteen minutes, which makes it possible to skim the milk of five to seven cows, and give the skimmed milk to the calves before it has lost its natural heat.

An electrically driven churn, which was installed in this same creamery, I could not get a photograph of, but its duty was to turn

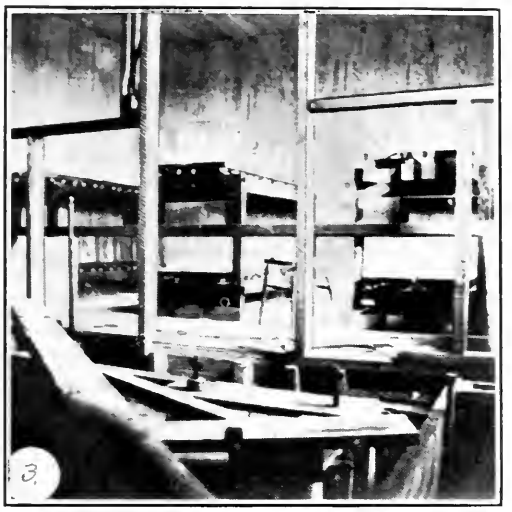


Fig. 3. Same battery, partly assembled, foundation for generating set in foreground. Partition separating battery room from engine room only partly completed.

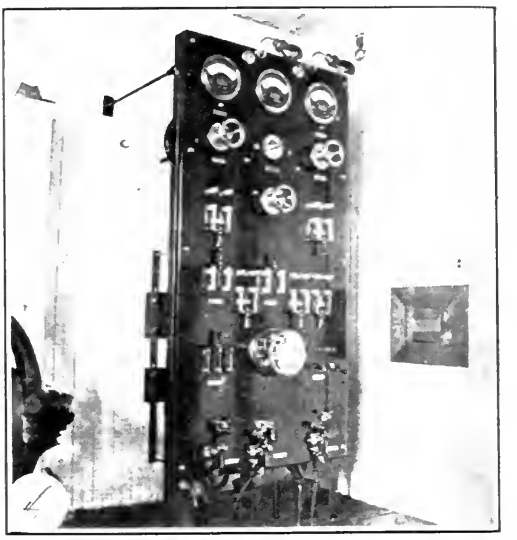


Fig. 4. Switchboard, showing station voltmeter in center at top of board with the battery ammeter on one side and the dynamo ammeter on the other. A recording watt hour meter is further down on the board, just above the circuit breakers.

out, daily, ten to twelve pounds of butter, which it would do in fifteen minutes.

An equipment, which can often times be installed and which will afford much convenience and profit, is that of electrical refrigeration. This is an important item and very little accurate information has ever been published on this subject. One reason is, that with the ordinary refrigerating machine the necessity of more or less constant attention has made the equipment so much of a nuisance that in many instances the operating expense made the use of the small refrigerating machine prohibitive.

To be practical for use on either the farm or the country estate we must have a refrigerating machine which does not involve a

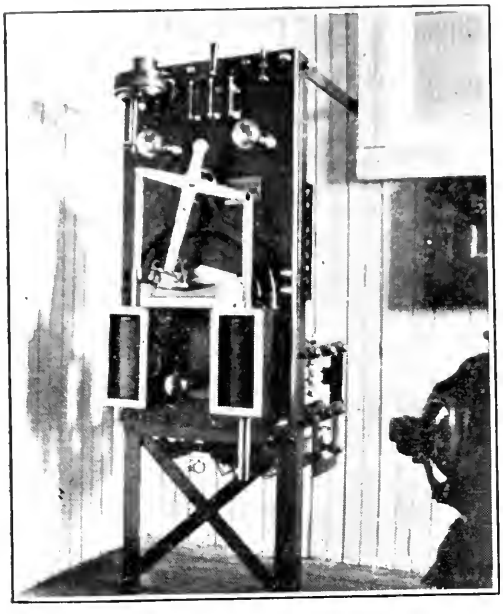


Fig. 5. While this view shows the voltage regulator installed in the Long Island plant, it is in its principal characteristics the same as I would use in any such plant. The panel itself is constructed like a switchboard. The differentially wound relay is seen at the top of the board. Its potential coil is wound for the station bus bar voltage. The differential coil and its shunt are so wound and adjusted as to counteract the natural drop of voltage of the system, which would otherwise occur, as the load passes from zero to the full load.

This device will control the voltage of the current supplied to the switchboard by the battery within one-half volt, above or below, that for which the regulator is set, and it will do this under any condition of battery voltage.

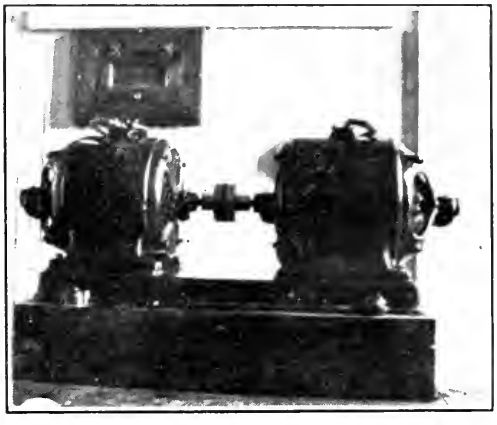


Fig. 6. The booster set consists of a direct current shunt wound motor coupled to a direct current separately excited generator.

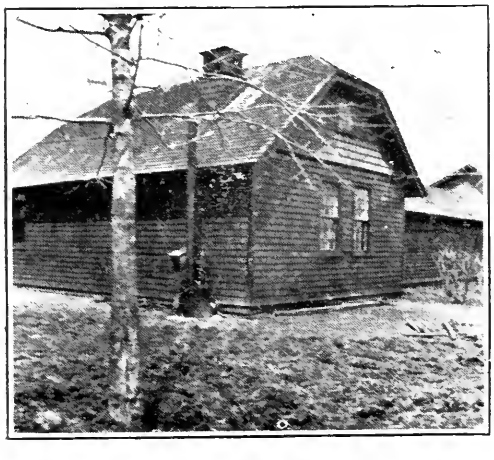


Fig. 7. Rear view of the power plant building.

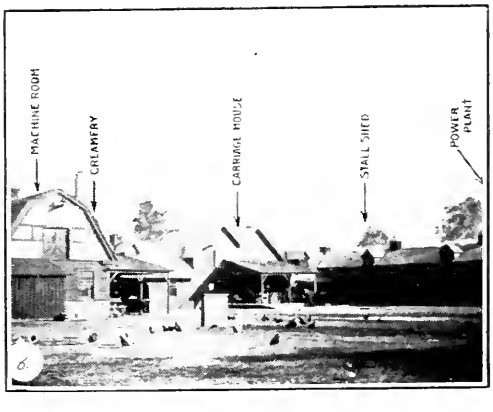


Fig. 8.

Fig 9.

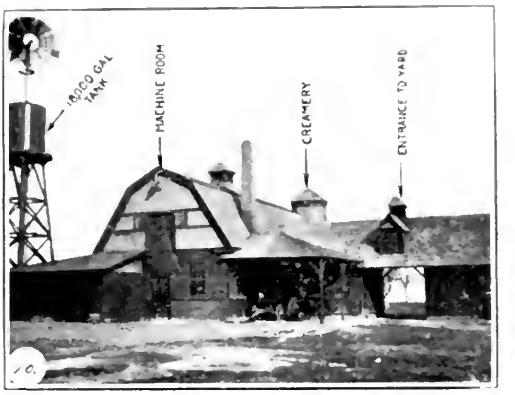


Fig. 10.

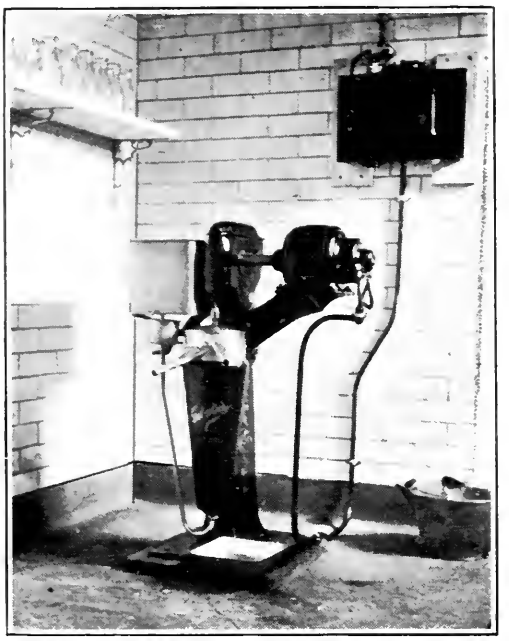


Fig. 11. Interior view in creamery, showing a Tubular Cream Separator driven directly by an electric motor. This equipment, as you will see, is well put up. It consists of a Crocker-Wheeler motor mounted on a bracket attached to a Sharples Separator.

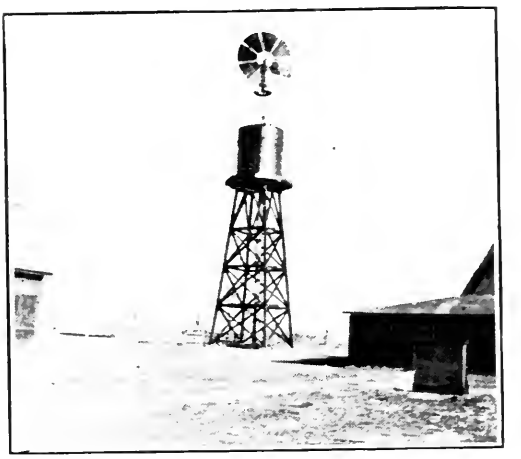


Fig. 12. This view shows the one great mistake of this otherwise ideal farm installation. This 18,000 gallon tank cost about as many hundred dollars, and could have been replaced with a one-horse power electric pump equipment, which would not have cost over two hundred dollars, and would have been much simpler, more reliable, and better suited to the owner's needs in every way.

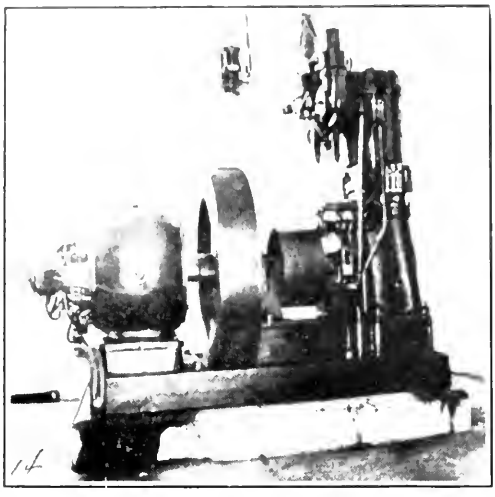


Fig. 14. Generating set of another plant.

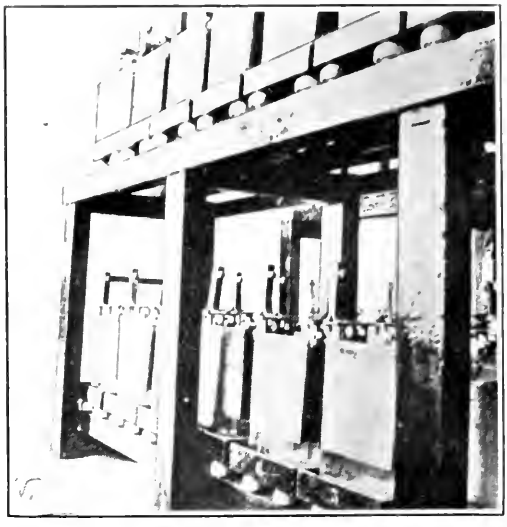


Fig. 15. Battery room for same.

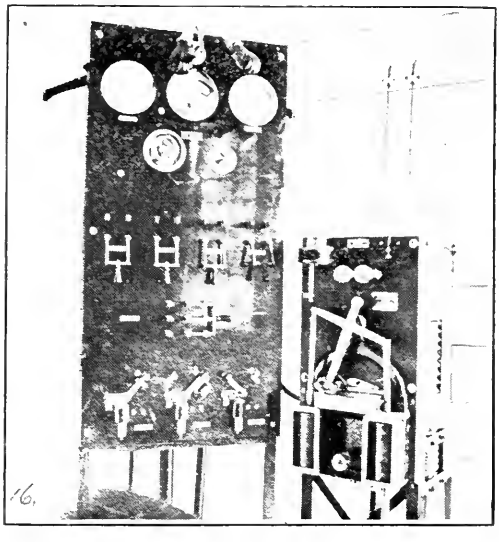


Fig. 16. Switchboard and voltage regulator.

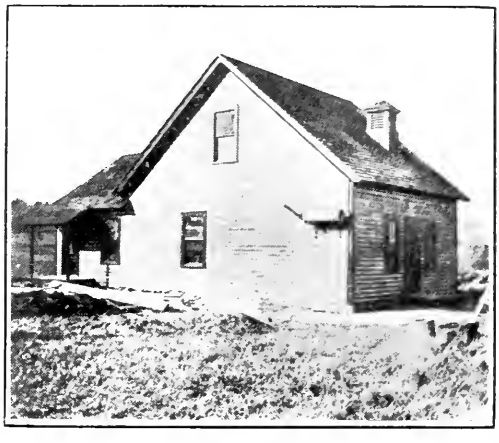


Fig. 17. Power plant building, inexpensive type. Combined with it are garage and living quarters for men.

Fig. 18. Residence containing the equivalent of about one hundred 16c.p. lamps.

high first cost or a high cost of maintenance, one which does not require the attention of a skilled mechanic and one of sufficiently compact proportions to permit of being housed in an inexpensive structure or out-building.

The automatic refrigerating machine fills these requirements. Equipments of this type are based on the direct expansion system.

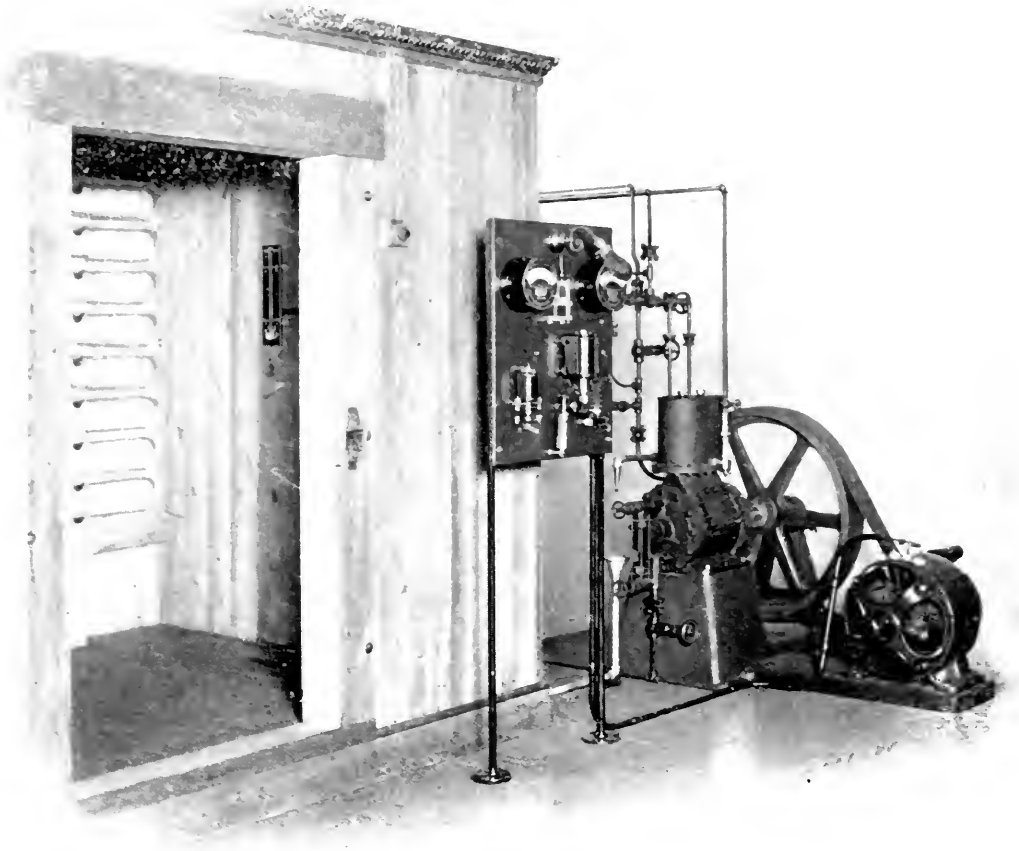


Fig. 19, illustrates the electrically operated automatic machine, refrigeration chamber and expansion pipes.

In carrying out the cycle of operation of the ordinary non-automatic refrigerating machines the compressors have to be oiled; the flow of water to the condenser has to be watched day and night to avoid the occurrence of dangerous pressures; the starting and stopping of the machine and the regulating of the flow of liquid ammonia through the expansion valves, has to be done by a skilled attendant.

Cold storage by means of ice has been made the subject of study

by many inventors and engineers, but this method in all its forms carries with it three inherent defects: the presence of considerable moisture or dampness, the impossibility of regulating and controlling the temperature and the constant waste of energy.

In isolated places, where no electric current is either generated or to be had from the public supply service, some form of gravity brine system would be more economical to adopt for the refrigera-

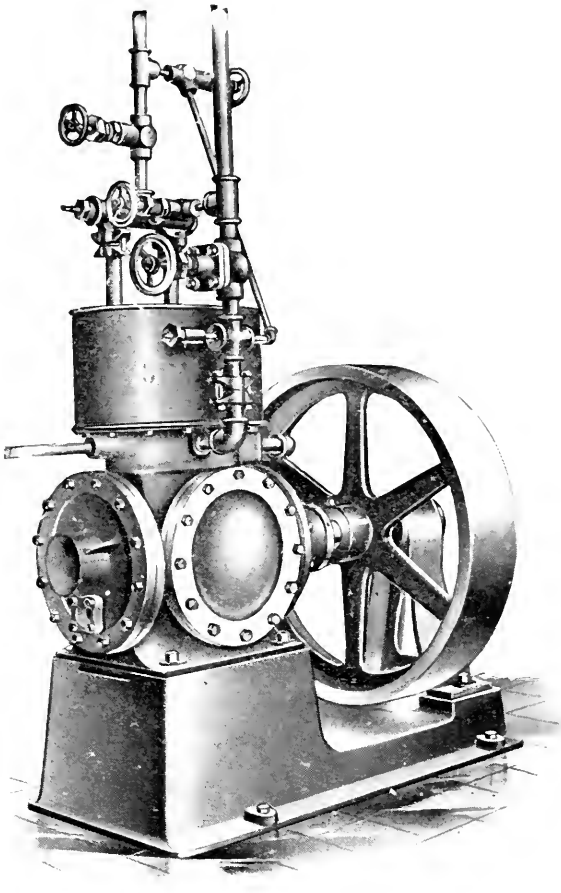


Fig. 20 shows the ammonia compressor alone.

tion of ordinary farm produce, such as eggs, butter, milk, cream, etc., than to attempt to run a refrigerating machine by power.

Where the electric equipment, however, has already been adopted for other purposes it is a very simple matter to extend its use so as to take care of the requirements of operation of an automatic refrigerating machine.

As the name implies, these machines take care of themselves, and they will maintain a temperature which shall not vary more

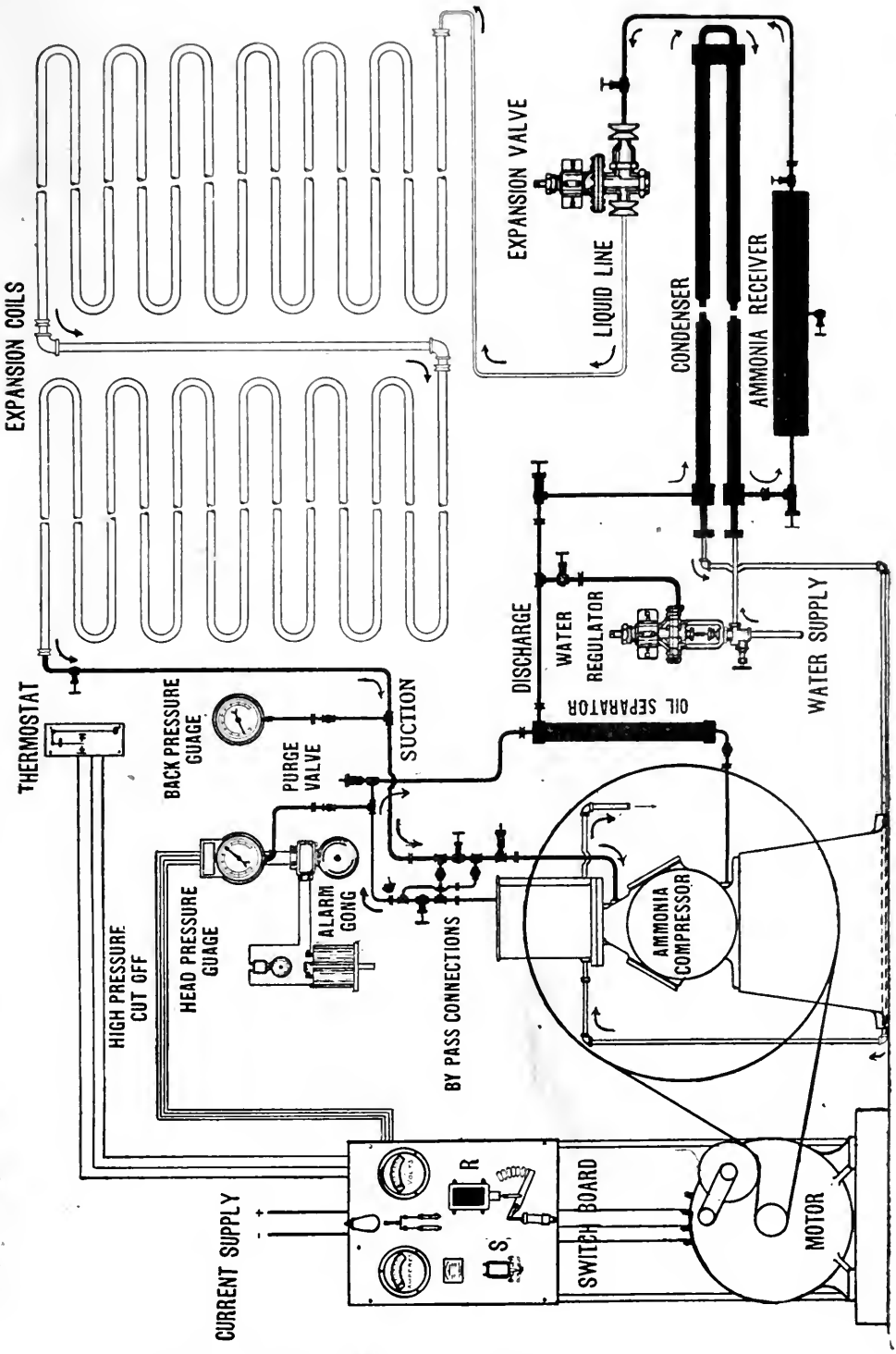


Fig. 21. Diagram showing complete automatic system.

than two degrees either up or down from the desired point, or, in other words, a range of 4°F., and the desired temperature may be selected to suit the necessities of the case.

Two important advantages of these machines are: first, that when the machine stops operating the water supply is automatically shut off, and second, when the electric motor, by which the machine is driven, has exerted sufficient energy, through the com-

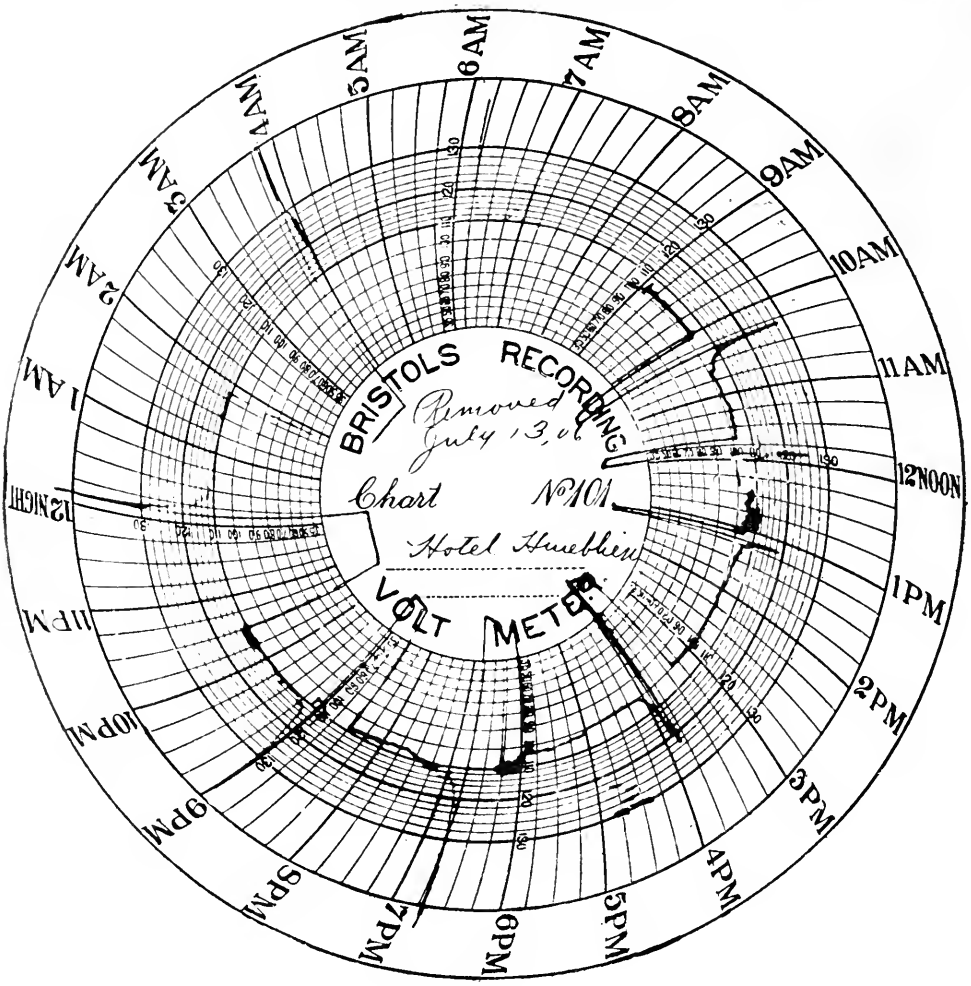


Fig. 22.

pressor, to reduce the temperature to the predetermined point, the current is automatically shut off. This latter action is under the control of a thermostat placed in the room or chamber where refrigeration is required.

A very pretty illustration of the saving which these machines give by automatically cutting off not only the supply of water but also the current during the periods when no energy is neces-

sary to maintain the desired degree of cold, is shown on slide, Fig. 22.

These records show that the compressor was in operation for only 75% of the total twenty-four hour period, during which the test was made.

Generally, a non-automatic machine must be shut down at night and the process of refrigeration continued by brine, but as the inherent efficiency of the brine system necessitates a machine more than twice the normal size on account of the shorter hours the cost of equipment is practically doubled. The electrically operated automatic machine, however, gives a twenty-four hour run unattended.

I have given the refrigerating machine subject perhaps more than its share of time this evening, but I think it will not be in vain, as it is, in my opinion, a most important one to the class of agriculturists for whom this paper is intended.

A point which I believe I have stated before, and which I wish to lay stress on, is that the successful farmer of the future can only be the man who will face his problems squarely and provide such means as may be necessary to turn out either better quality or the same quality at a lower cost.

Let us assume, therefore, that for other reasons an electric plant has been installed, it then simply becomes a matter of calculation to determine whether or not by having the means at hand whereby produce may be kept in proper condition from a period of low prices to one of high values, the labor saved in harvesting and daily handling ice, and the more healthy condition of using ice artificially made from pure well or spring water, justify the outlay for the apparatus.

As far as the electric current required is concerned, it will be found, by a reference to the weather bureau reports, that the daily period of day light throughout the year corresponds very closely with the temperature. Consequently, with a well proportioned generating plant it would not be necessary to provide any greater capacity to take care of the refrigerating machine than had already been provided for the other power apparatus and the lighting load.

Almost any dry, clean cellar will serve as a cold storage room.

Apples can be kept in this way in perfect condition until the price has gone up high enough to net probably twice as much as

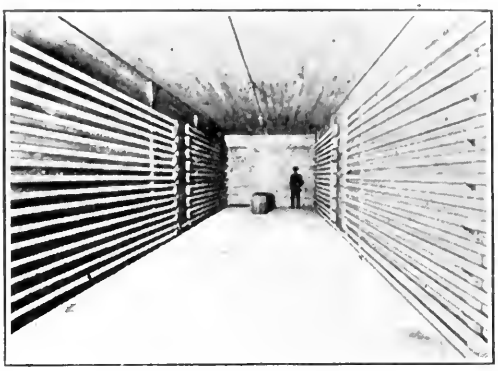


Fig. 24. Refrigeration coils on cellar walls.

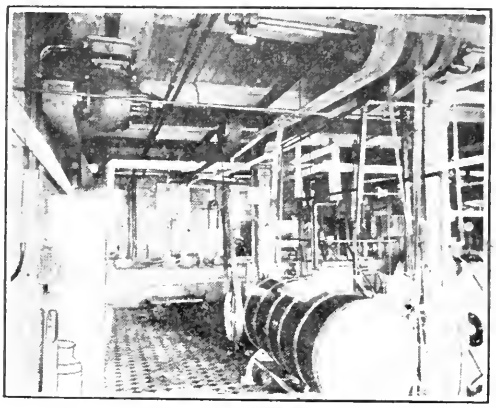


Fig. 30. "Northern" motor driving churns, milk heater, butter worker, etc., in modern dairy.

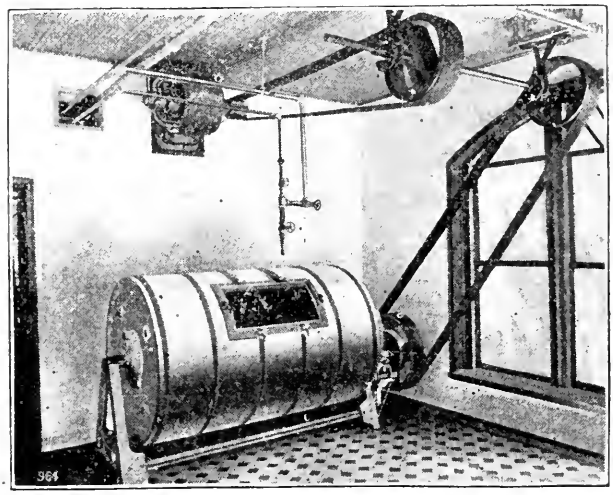


Fig. 31. "Northern" motor driving Fargo churn.

it would be possible to obtain at the time of picking the fruit. This, of course, applies equally well to all fruits, poultry, eggs, butter, etc.

The many little domestic electrical devices, such as flat irons, plate warmers, sauce-pan heaters, sewing machines, fans, etc.,

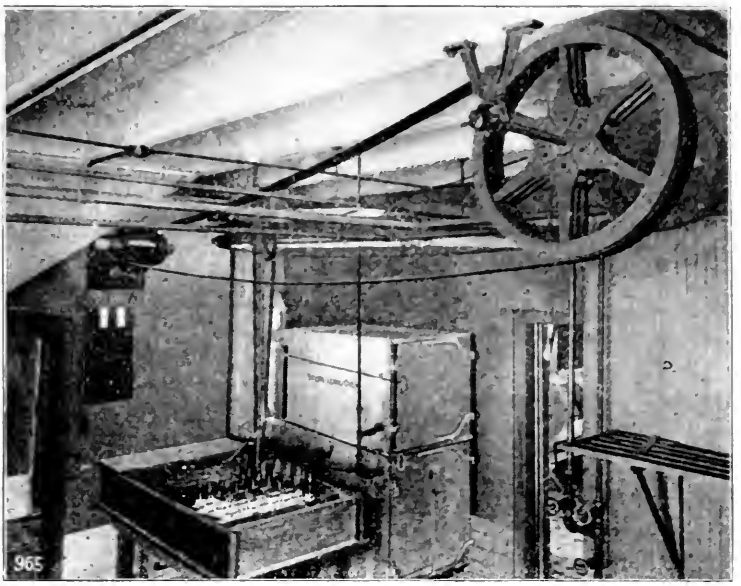


Fig. 32. "Northern" motor driving bottle washing machine and pasteurizing apparatus in a modern dairy. Pasteurizing equipment in the room at the right.

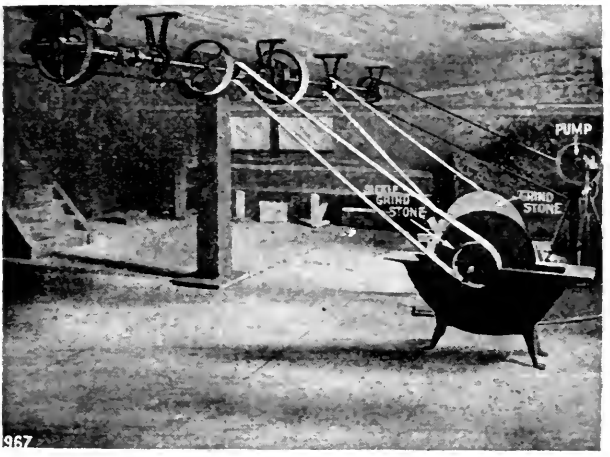


Fig. 33. "Northern" backgear motor driving grindstone and deep well pump.

which have from time to time found their way to the public, are too well known for me to more than mention, and in the stable; electric horse clippers, dental floats and grooming machines are to be seen in daily operation. But electrically operated pneumatic floor sweepers, ice cream freezers, dough mixers, churns, cream

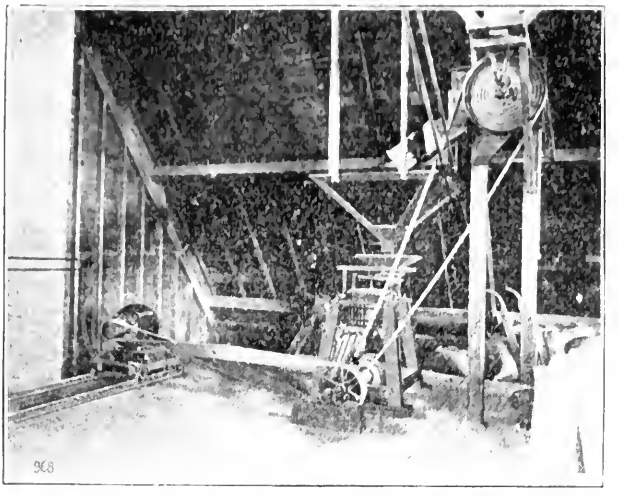


Fig. 34. "Northern" motor driving Nordyke & Marmon corn mill.

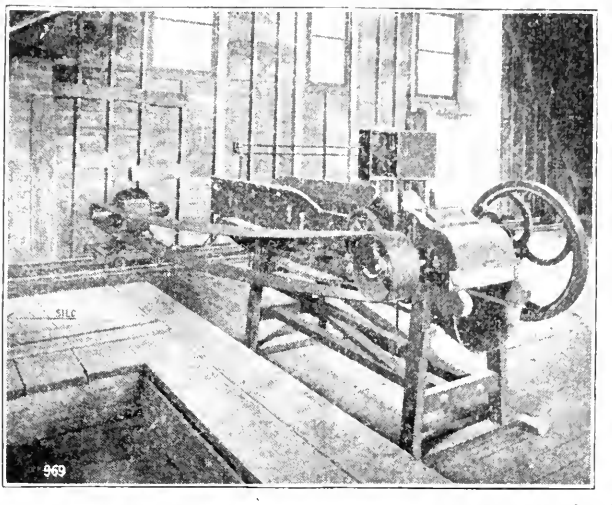


Fig. 35. "Northern" motor driving Smalley ensilage cutter in dairy barn.

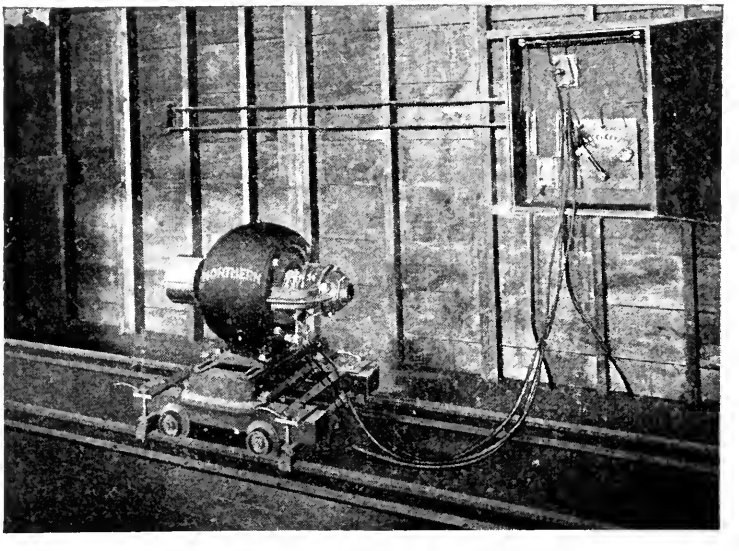


Fig. 36. "Northern" motor mounted on track in dairy barn. This motor serves to drive both the corn mill in Fig. 34 and the ensilage cutter in Fig. 35. It travels on rails, making it easy to set in running position and easily kept in alignment.

separators, feed mixers and grinders of all kinds, milking machines and chicken hatchers, are things we do not see every day.

I have been fortunate enough to obtain good photographs of many of these, and I have had slides made to show you that they are not mere fancy, but are practical and their use will, before a great while, be very general.

One can hardly glance at the newspapers nowadays without seeing an account of some serious conditions which have been brought to light through our modern day methods of testing cows and their milk for the presence of disease germs.

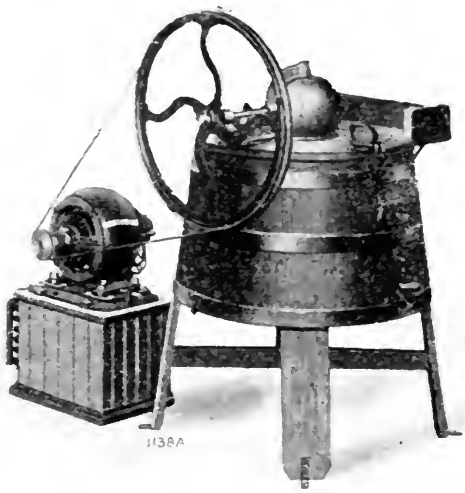


Fig. 37. "Northern" motor driving "Ocean-wave" washing machine.

I do not think that the fact that we hear a great deal about this sort of thing indicates that the average milk supply is to-day worse than it used to be, but people are getting to realize more the necessity for strictly sanitary conditions, and are demanding improvements which will insure that they may have them.

Sanitary milk, therefore, is worth considerably more than that in regard to which there is question.

The thing which has always been a problem to me is that under the conditions which obtain in, I may say, a majority of the dairy barns, that there are not many times more disease germs in the milk than bacteroligists report.

The milking machine has opened up a new idea in this direction and, in my opinion, represents a most decided step in advance in farm practice. In fact, I do not hesitate to prophesy that it will, before a great while, revolutionize the milking business.

The principles upon which the best mechanical milking systems have been developed may be described briefly as follows: The cow, with all its peculiarities in regard to giving up her milk, is, through the agency of mechanical devices, connected directly through a system of tubing, with the milk bottle itself, if you please, and is made to give up her milk, which she does, if the machine is properly applied, more willingly and in greater quantity than she would to the average hand milker.

It will be seen, therefore, that there is no possible way in which germs can enter the milk from outside sources from the time the milk leaves the cow until it is bottled or put up in shipping cans.

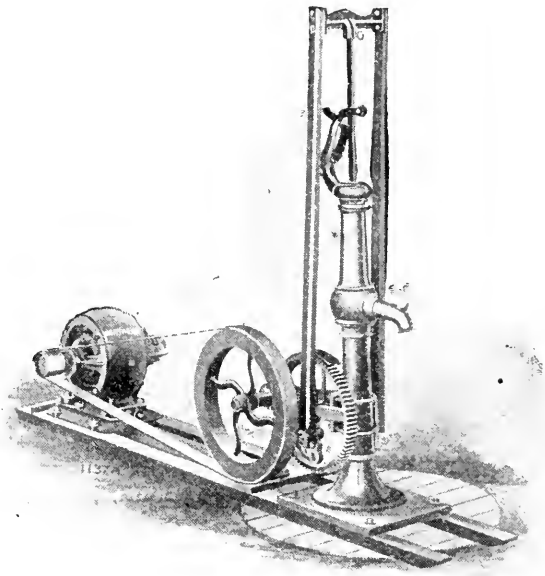


Fig. 38. "Northern" motor driving Fuller & Johnson No. 3 pumping jack.

This statement is, of course, made on the assumption that the mechanical devices and conveyor tubing shall at all time, when not in use, be kept sterilized, which, of course, they should be.

Some skeptics may say this cannot be done, but my answer is that, if a surgeon cannot keep his instruments clean, he is not qualified to practise surgery.

It consists essentially of a strong tin pail, weighing about twelve pounds and holding 54 pounds of milk, smaller at the top than at the bottom, with cast metal cover fitting loosely, but resting on a rubber gasket, which makes an air-tight joint. On the cover is mounted the pulsating mechanism, and from it project three nipples, on one of which is slipped the hose which connects with

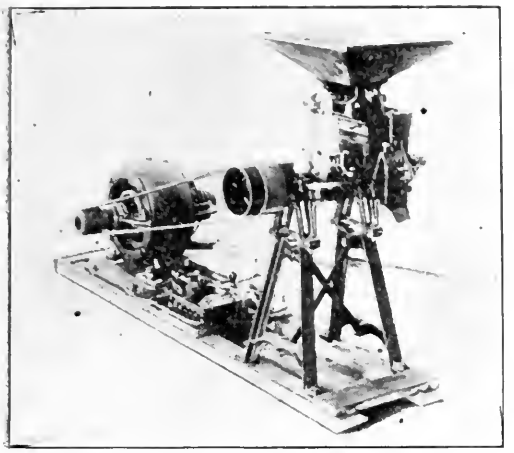


Fig. 39. "Northern" motor driving No. 6 duplex corn mill.

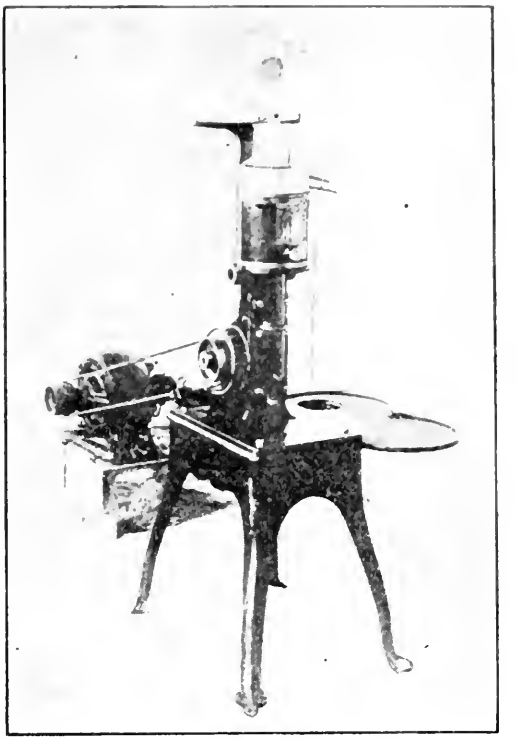
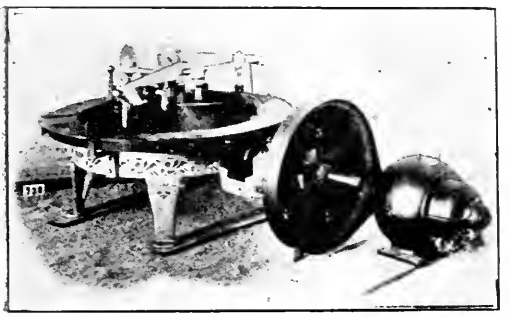


Fig. 40. "Northern" motor driving a DeLaval cream separator.



No. 4.1 "Northern" motor driving Dayton cream beater.

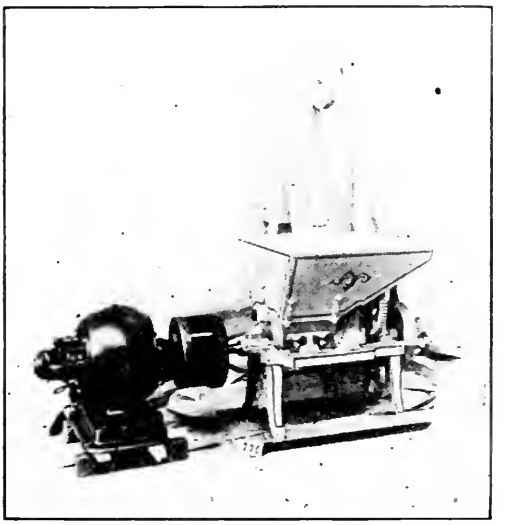
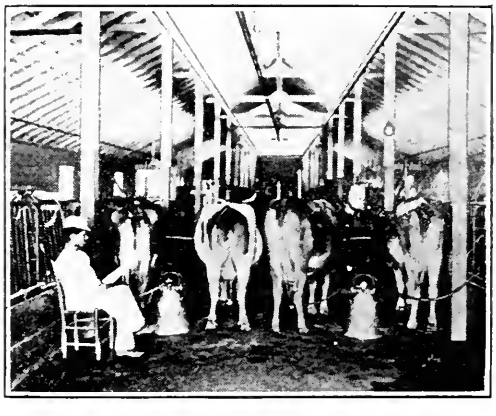


Fig. 42. "Northern" motor driving Marseilles corn mill through flexible coupling.

the stanchion cock in the piping system, and on the other two the rubber tubing which leads to the two cows. These two nipples are provided with cocks. As the milk enters it passes through a short piece of glass tubing, and by watching this we know when milking is completed. The other end of each of these rubber milk-tubes, which are 3½ feet long, is attached to a small metal con-

Fig. 43 shows the milking machine itself.

Fig. 44 shows that one machine will milk two cows at a time, and one man can attend three or four machines.



In Fig. 45 you will see the usual litter and feed carrier rail over-head. These carriers are, so far as I know, universally propelled by hand. A plan which I would like to see employed for this would be an electrically driven and controlled telpher. I believe it would tend greatly to decrease the time which is required for feeding and properly cleaning out the cow barn.

nector, which has four outlets, from each of which a short rubber tube leads to a teat-cup, which is made of tinned metal and provided with a rubber mouthpiece to fit around the base of the teat.

There are five sizes of these teat-cups to fit different sized teats, and the chief skill of the operator is in choosing the right size. When these are slipped on over the teats they stay there by at-

mospheric pressure until removed by the attendant. It will be easily understood that the effect of the vacuum is to draw the milk from the teat to the pail; but this is not enough. When this is done the teat is empty, more milk cannot get into it from the udder, and the performance stops. To prevent this a contrivance has been added which breaks the vacuum, and then a fresh supply of milk enters the teat; then the vacuum is created again and this

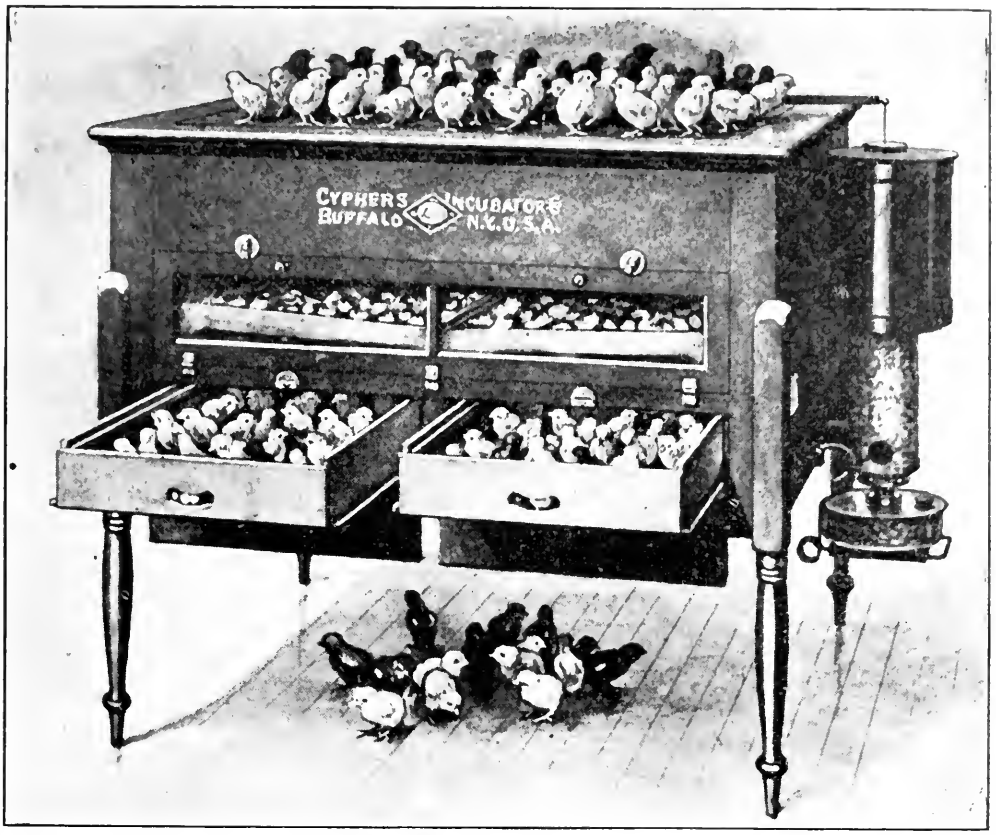


Fig. 46.

additional milk goes to the pail, and so on until the milking is completed.

The vacuum pump must of course be driven by some source of power. The power may be of any kind, electric motor, gasolene engine, tread power or a steam engine. If the steam engine be used, it follows that there will be plenty of real hot water on hand for cleaning purposes, but this advantage, however, may be obtained by having a sterilizer of suitable proportions to perform the work of cleansing. This sterilizer can be heated by coal, gas or electricity.

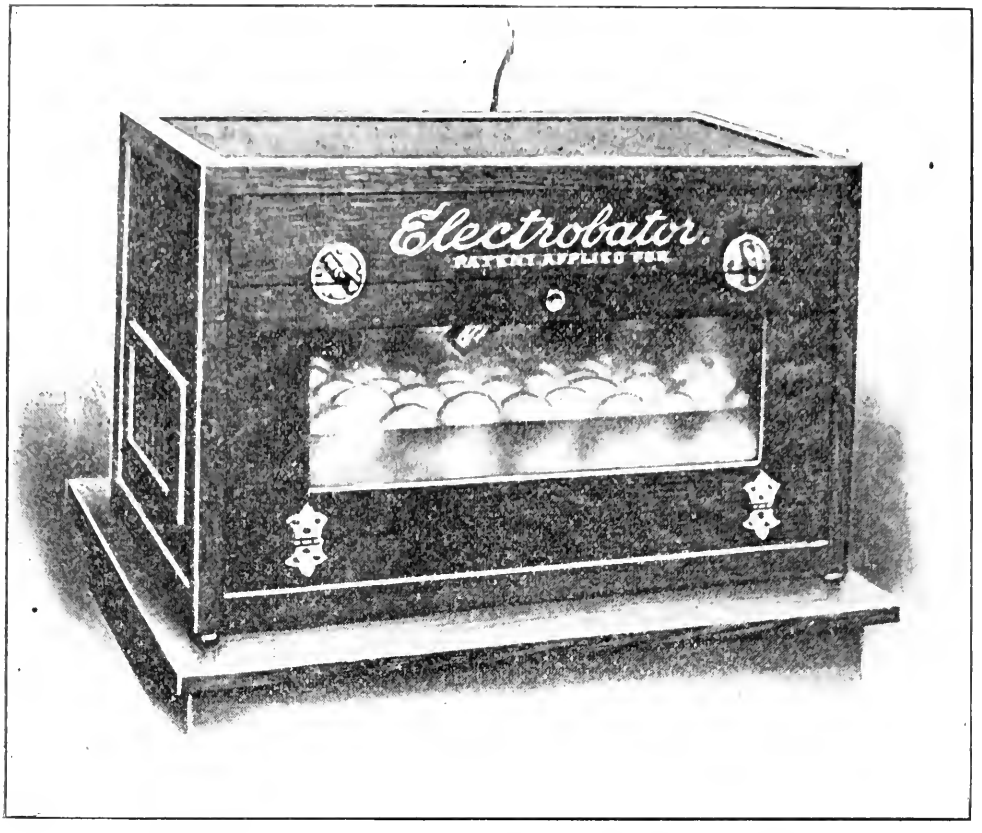


Fig. 47. An electrically heated and regulated incubator.

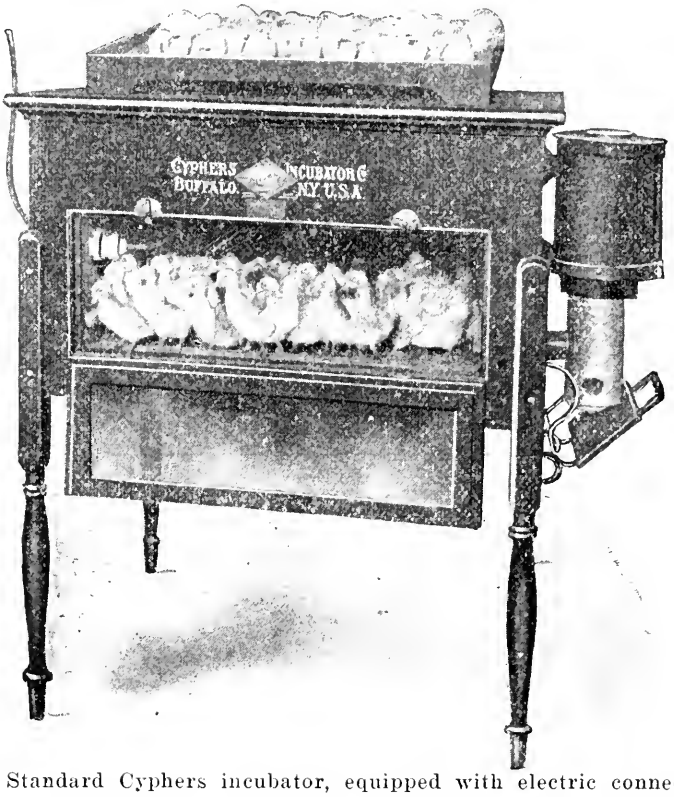


Fig. 48. Standard Cyphers incubator, equipped with electric connection and electro-plane heater

Fig. 49. An electric, self-regulating, fire-proof heater designed for use in Standard Cyphers, No. 0 and No. 1, Incubator, and in other makes of incubators of similar capacity.

Fig. 50. Electric hover in use in exercising compartment of a Cyphers Colony Brooder.

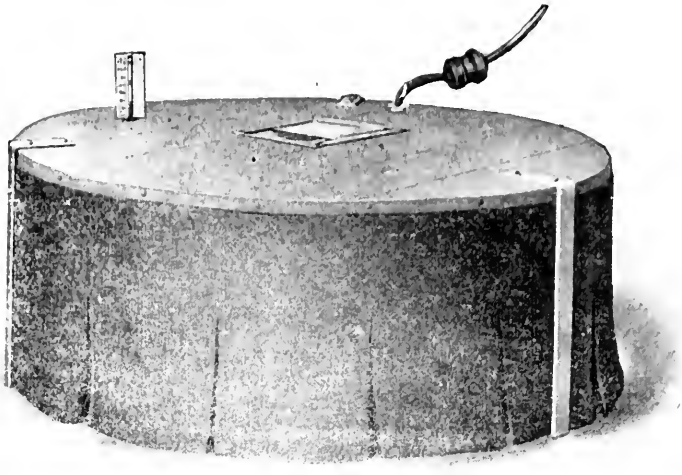


Fig. 51. An electrically-heated, self-regulating brooding device for use in any make of brooder, either in-door or out-door, that is sufficiently large to accommodate a hover twenty-four inches in diameter and ten inches in height.

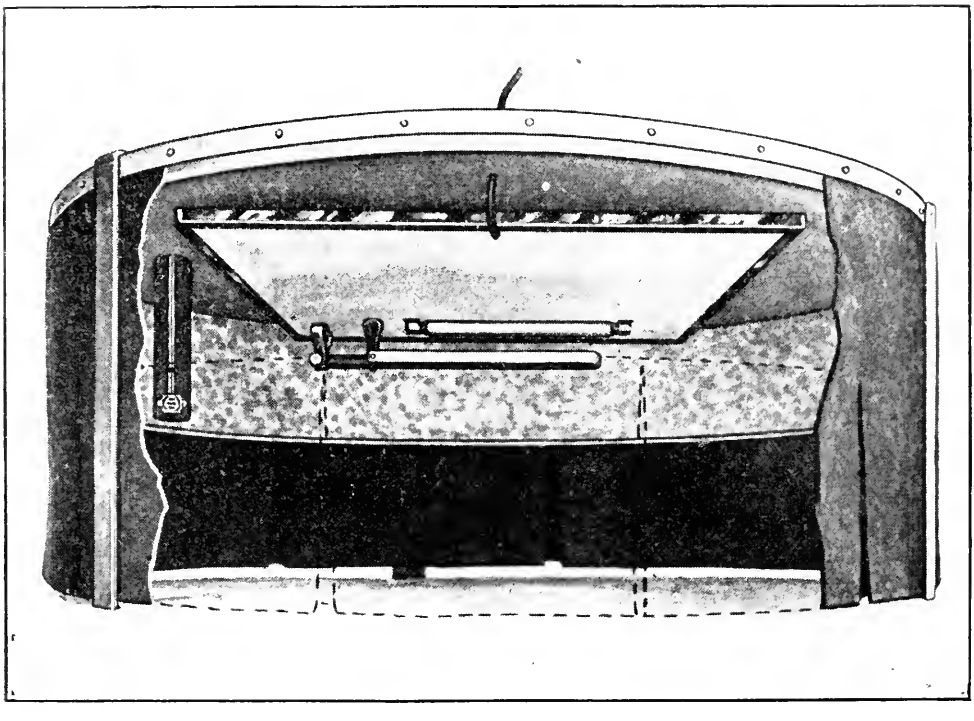


Fig. 52.

The electric motor will without doubt be found to be the most convenient and efficient source of power, as cows are only milked twice a day, and those in attendance have other duties to perform during the remainder of the day. With the motor the power is on or off when you throw the switch, which is not the case with a steam engine and boiler.

The cow-milker which my slides illustrate is the "Burrell-Lawrence-Kennedy."

I have not spoken of the economy of these machines, but at a glance it will be seen that the sanitary advantage, while most important, from the public's point of view, is not the only one which will appeal to the dairyman.

Before bringing this paper to a close I must not forget to pay tribute to the ever cackling hen, which no longer is to be allowed to hatch her brood of chicks in peace and comfort. The necessity of increased output has reached her also.

As a result of a series of experiments one of the leading incubator companies has recently placed on the market some ingenious and practical apparatus whereby hatching and brooding of chicks and ducklings is accomplished by electricity obtained from ordinary lighting or power fixtures in residences or other building. The idea is a very simple one, and it has been cleverly worked out, as you will see from the accompanying slides.

TEN THOUSAND DOLLARS AWARDED ART STUDENTS.

With the closing of the year of the Schools of the Pennsylvania Academy of Fine Arts, the oldest and most widely known art school in America, the announcement was made on Thursday, May 28th, of the award to eighteen of its students of travelling scholarships of $500.00 each for four months' travel and study in Europe.

These Scholarships, known as the William Emlen Cresson Memorial Scholarships, are each year available by the Academy, which has already sent forty-three pupils abroad under the Cresson foundation.

The effect upon the art of this country of the policy adopted by the Pennsylvania Academy is bound to be far-reaching, and indeed, is already noticeable in our current exhibitions wherever held.

The scholarships this year were awarded: Two in the Department of Architecture, two in the Department of Illustration, two in the Department of Sculpture, and ten in the Department of Painting.

In addition to the Travelling Scholarships the Academy's prize list is large in all its departments. The principal prizes being the Edmund Stew-

ardson in Sculpture of $100.00, awarded this year to Beatrice Fenton, of Philadelphia; the Henry J. Thouron in competition of $50.00 each, awarded to Nathaniel J. Pousette and Lawrence B. Saint; Henry J. Thouron Prize of $25.00 each, awarded to Henry L. Wolfe and Juan N. Arellano, who comes to the Academy from the Philippine Islands; Charles Toppan Prize of $400.00, to H. Willard Ortlip, of Norristown, Pennsylvania, and the Charles Toppan Prize of $300.00 to Adolph W. Blondheim, of Philadelphia.

The Faculty of the Pennsylvania Academy of the Fine Arts is composed of the following distinguished artists: Herbert M. Howe, M.D., Chairman; Thomas P. Anshutz, Hugh H. Breckinridge, William M. Chase, Henry McCarter, Paul Phillippe Cret, George McClellan, M.D., Cecilia Beaux, Frank Miles Day, Henry R. Poore, W. Sergeant Kendall.

Book Notices.

Electro-Analysis, by Edgar F. Smith, Professor of Chemistry, University of Pennsylvania. Fourth edition, revised and enlarged. 336 pages, illustrations, 12-mo. Philadelphia, P. Blakiston's Son & Co., 1907. Price, in limp leather, $2.50.

The first edition of this work was issued in 1890 as a text-book for students in electro-chemistry. From a book of about one hundred pages it has grown to an imposing volume of three hundred and thirty-six pages.

The present edition has been completely revised, and much new material has been added. Innumerable references to existing literature add to the value of the book. R.

The Blast Furnace and the Manufacture of Pig Iron. An elementary treatise for the use of the metallurgical student and the furnaceman, by Robert Forsythe. 368 pages, illustrations, 8-vo. New York, David Williams Co., 1908. Price, $3.00.

This volume is designed chiefly for the use of beginners. It contains a simple and concise statement of the general principles of the manufacture of iron and the operation of the blast furnace.

Marginal references throughout the book make it possible for the student to inform himself more fully on any branch of the subject.

The author, a graduate of Harvard University, and for three years instructor in metallurgy in the same institution, died while the work was being prepared for the press. It has been carried to completion by a friend, who has followed the plans as outlined. A. R.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 2 83RD YEAR AUGUST, 1908

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

The Modifications of the Kjeldahl Method For the Quantitative Determination of Nitrogen.

Thesis Presented to the Faculty of the Central High School of Philadelphia in Partial Fulfilment of the Requirements for the Degree of Master of Arts.

BY JOSEPH SAMUEL HEPBURN, A.B., B.S. in Chem., M.S. 108th Class,

And submitted for publication in the Journal of the Franklin Institute.

The element nitrogen is an absolute essential for organized matter, since it is a constituent of the proteins which occur in all forms of plant and animal life. Nitric acid and the nitrates play a prominent part in the arts, especially in the manufacture of fertilizers and in the preparation of nitro-glycerin, gun cotton and aromatic nitro compounds for high explosives. Nitrogenous compounds form the greater part of the large and growing family of coal tar dyes, among which may be mentioned those triumphs of synthesis, artificial indigo and alizarin. Synthetic

organic chemistry has given to medicine a host of remedies which contain nitrogen, such as antipyrine, antifebrin and phenacetin. Nitrogen is found in the alkaloids, in prussic acid—an exceedingly virulent poison; in ammonia—a powerful base; in various products of animal and vegetable origin, such as mustard oil and the derivatives of uric acid, and in a great series of synthetic compounds like the osazones which have been so helpful in the study of the structure of the sugars.

The quantitative determination of an element so widely distributed is of the utmost importance and has been the subject of careful study by many investigators. The methods of analysis fall into three classes, represented by Dumas, Will and Varrentrapp and Kjeldahl. The year 1908 marks the twenty-fifth anniversary of the publication of the original method of Kjeldahl.

The first method for the quantitative determination of the nitrogen content of an organic compound was the absolute method of Dumas. He heated the compound with cupric oxide in an atmosphere of carbon dioxide, reduced any oxides of nitrogen by means of a glowing spiral of metallic copper, passed the gases through a solution of potassium hydroxide and measured the volume of residual nitrogen.

Later on, Will and Varrentrapp devised a method for obtaining the nitrogen in the form of ammonia by heating the nitrogenous compound with soda-lime to redness; the ammonia was collected in hydrochloric acid and weighed as ammonium chloroplatinate. Peligot modified this process by using a known amount of standard acid, and then titrating the excess of acid. The methods of Dumas and Will and Varrentrapp required that the compound be in a fine state of division; solutions had to be evaporated to dryness and the residue finely divided.

Kjeldahl (1) worked on brewery materials and wished to determine the nitrogen content of various solutions without evaporating them to dryness. First he tried Wanklyn's method for determination of albuminoid nitrogen, which depends on distillation with alkaline permanganate; the yield of nitrogen was incomplete. Better results were obtained by boiling with potassium permanganate and dilute sulphuric acid, making alkaline with a fixed alkali, distilling into standard acid, and titrating the excess of acid. Finally the substance, whose nitrogen content was to be determined, was heated with concentrated sulphuric

acid and completely oxidized with permanganate. Kjeldahl says: "The principle of the new method, therefore, is to heat the substance in question for some time with a sufficient quantity of concentrated sulphuric acid to a temperature which is close to the boiling point of the acid, and then to oxidize the solution thus obtained with an excess of dry, powdered permanganate." He recommends heating with sulphuric acid, to which some fuming sulphuric acid and phosphoric anhydride have been added, for two hours. The dark solution is to be removed from the flame and the oxidation is to be completed by means of an excess of dry, finely divided potassium permanganate, which is added, a little at a time, in the form of a stream of dust. The dark solution becomes lighter, then colorless, finally dark green, or blue green if phosphoric anhydride be present. The solution may be heated gently, but not strongly, or nitrogen will escape. Kjeldahl diluted the solution, transferred to a distilling flask, made alkaline with a fixed alkali after adding zinc turnings to prevent bumping, distilled into a known volume of standard acid, added potassium iodide and iodate and titrated the liberated iodine with standard sodium thiosulphate. The per cent. of nitrogen was then calculated. Kjeldahl published excellent results on the determination by his method of the nitrogen content of twenty-three aliphatic and aromatic compounds, as well as naturally occurring bodies. Certain alkaloids, cyanogen and nitro compounds, gave poor results.

Heffter, Hollrung and Morgen (2) made two determinations of the nitrogen content of sixty-five substances by the method of Will and Varrentrapp, and duplicate determinations on the same substances by Kjeldahl's method. The means of the determinations by the two methods checked well, the average difference being 0. 084%. The Kjeldahl method gave more nitrogen in 94% of all the determinations. They digested 1 to 1.5 grams of the substance with 2 grams of phosphoric oxide and 20cc. of a mixture of 4 volumes of pure concentrated sulphuric acid and 1 volume of the fuming acid. Heat was applied with a small flame until foaming ceased; then the solution was boiled, since this is essential for complete oxidation. The maximum period of digestion was five hours.

Petri and Th. Lehman (3) applied the process of Kjeldahl, including oxidation with potassium permanganate, to the de-

termination of the nitrogen content of ammonium sulphate, urea, uric acid, hippuric acid, kairin A (ethyl hydroxytetrahydraquinoline), and normal, diabetic and albuminous urines. They distilled the ammonia in a current of steam.

Pflüger and Bohland (4) digested urine with a mixture of equal parts of concentrated and fuming sulphuric acid, omitting the oxidation with permanganate. In a later paper (5) they recommend digestion of urine with fuming sulphuric acid.

Kreusler and Henzold (6) noticed that, during the distillation, the steam, which passed over with the ammonia, dissolved fixed alkali from the walls of the glass condenser, which neutralized the receiving acid and so caused a result which was too high. Kreusler (7) called attention to the fact that fuming sulphuric acid carries oxides of nitrogen, which reduce to ammonia during the digestion and thus increase the percentage of nitrogen. He used a solution of 200 grams of phosphoric oxide in 1 liter of rectified sulphuric acid.

Dafert (8) concluded that the sulphuric acid removes hydrogen and oxygen from the organic body in the proportions necessary to form water. The heating of the resulting carbonized mass with sulphuric acid evolves sulphur dioxide, which reduces the nitrogenous substance; the resistant nitrogen compounds thus formed are decomposed on the addition of potassium permanganate with the production of ammonium compounds. The quantity of ammonia formed depends essentially upon the length of the period of digestion; if this be sufficiently long, nearly all nitrogenous bodies will allow the complete conversion of their nitrogen content into ammonia. However, since the period of digestion, required by a new compound, cannot be foreseen in any way but must be ascertained in each case by special examination, the Kjeldahl method cannot replace entirely the method of Dumas. Dafert later (9) divided nitrogenous compounds into two classes. The first class may be examined by the Kjeldahl method without any previous reduction or other treatment; to it belong the amines, ammonium compounds, pyridine and quinoline derivatives, alkaloids and bitter principles, proteins and allied bodies. The second class includes all compounds which require a previous treatment, such as nitro, nitroso, azo, diazo, and amidoazo compounds, hydrazines and all the compounds of nitrous and nitric acids; in a word, all those compounds in the mole-

cules of which a nitrogen atom is linked to an oxygen atom or atoms, or to a second nitrogen atom.

Czeczetka (10) recommends that a saturated solution of potassium permanganate in pure, concentrated sulphuric acid be substituted for the solid salt in the final oxidation. The permanganate solution is run slowly into the solution to be oxidized by means of a tap-funnel with a long stem. Care must be taken that the permanganate solution flows into the digested solution without falling upon the surface of the latter; otherwise the reaction occurs with explosive violence.

Bosshard (11) applied the original method of Kjeldahl with excellent results in determining the nitrogen content of allantoin, and of a number of amino acids, including leucine, tyrosin, asparagin, aspartic, glutaminic and amido-valeric acids. He cautions against the use of sodium hydroxide containing nitrate in the distillation, since the nascent hydrogen, produced by the reaction between the zinc and sodium hydroxide, reduces the nitrate to ammonia and thus increases the percentage of nitrogen. Bosshard also noticed that, whenever a great excess of zinc and sodium hydroxide solution was used, sodium hydroxide was carried over mechanically by the hydrogen gas, and was titrated as ammonia. A ball filled with glass beads failed to hold back all of the mechanically carried alkali. However, the error may be overcome by avoiding a great excess of the reagents, or by the use of a safety distilling bulb such as that invented by Pfeiffer and F. Lehmann (12) and improved by Rindell and Hannin (13), or that devised by Reitmair and Stutzer (14).

Wilfarth (15) noticed that the presence of copper salts appreciably reduced the time required for the digestion; he tested the effect of the oxides of iron, mercury, maganese, bismuth, zinc, lead and copper on the digestion of materials such as clover hay and peas. One gram of material and one gram of oxide were digested with concentrated sulphuric acid and phosphoric anhydride until a bright Rhine wine color appeared. Digestion proceeded more rapidly when the oxides were added than when they were absent. Mercuric oxide reduced the time factor to one-eighth that of the plain digestion, but mercur-ammonium compounds formed in the distilling of the ammonia and caused a loss of nitrogen. Therefore, experiments were tried with cupric oxide.

The effect of the cupric oxide depends entirely on the quantity of oxide in solution; 20 cc. of concentrated or fuming sulphuric acid will dissolve 0.1 gram of oxide, but the same volume of acid will dissolve 0.2 gram of oxide in the presence of 4 grams of phosphoric anhydride, and 0.6 gram of oxide in the presence of 10 grams of anhydride. Wilfarth states that the cupric sulphate plays a catalytic rôle in the oxidation of the organic matter. For each digestion he used either 0.5 or 1 gram of monohydrated cupric sulphate and 20cc. of a solution of 250 grams of phosphoric anhydride in 1 liter of concentrated sulphuric acid. The mixture was heated until either colorless, or a wine red, when it was oxidized with permanganate. This method was applied with success to various materials of animal and vegetable origin, such as leather and oil cake.

In a second paper (16) Wilfarth states that the time factor is almost the same when ferric oxide is substituted for cupric oxide, but both the green color of copper and the yellow one of iron mask the end point of the digestion.

Mercuric oxide is more soluble in sulphuric acid, hence acts as a better catalyser, and it possesses the additional advantage of forming a colorless solution. Oxide, free from nitrate, prepared by the wet method, should be used; for it may be substituted a chemically equivalent quantity of metal or sulphate. One gram of substance should be digested with 0.7 gram of mercuric oxide and 20cc. of a mixture of 300cc. of concentrated and 200cc. of fuming sulphuric acid, without the addition of phosphoric anhydride, until completely colorless; 0.6 gram of the oxide dissolves while the other 0.1 gram prevents bumping during the digestion. While oxidation may be completed with permanganate after the solution becomes wine red, a loss of nitrogen may then occur. When mercuric oxide is substituted for cupric oxide, the time factor for a digestion is reduced to one half. The formation of mercur-ammonium derivatives during the distillation of the ammonia is prevented by an addition of potassium sulphide solution. The Official Agricultural Chemists in their modification of this method (17), direct the use of 25cc. of a solution of 40 grams of sulphide in 1 liter of water.

Warington (18) and Reitmair (19) have devised methods whereby the organic nitrogen alone may be determined when a mixture of an organic compound and a nitrate is the subject of

analysis. Warington directs a preliminary heating of the mixture with an excess of ferrous sulphate and strong hydrochloric acid to expel the nitric nitrogen; the solution is then evaporated to dryness, concentrated sulphuric acid is added and the digestion is carried out in the usual way to determine the organic nitrogen. Reitmair places one gram of the finely powdered mixture in a dish of tin foil, adds 3cc. of 50% sulphuric acid, stirs well with a glass rod, dries in the oven 3 to 4 hours at 60° to 80°C., then for one hour at 120°-130°C. The moist mass is now free from nitric acid, and is digested in the usual way.

Several investigators have modified the method of Kjeldahl so that it may be applied in the determination of the nitrogen content of nitrates and nitro compounds. Stebbins (20) digested 0.25 gram of material with 0.5 gram of sucrose, 2 grams of phosphoric anhydride and 20cc. of a mixture of four volumes of sulphuric acid of 66°B., and one volume of the fuming acid; oxidation was completed by means of permanganate. Results, correct to a few tenths of one per cent., were obtained with dinitrobenzol, meta nitraniline, and ortho nitrophenol.

Asboth (21) mixed 0.5 gram of such substances as azobenzol, nitrobenzol and picric acid with 1 gram of sucrose and digested with cupric sulphate and sulphuric acid, as directed by Wilfarth, without use of potassium permanganate. The same process was applied to cyanide, ferrocyanide and ferricyanide of potassium, sodium nitroprusside and ammonium thiocyanate, as well as to cyanuric acid. With nitrates, sucrose was replaced by benzoic acid; for each half gram of potassium nitrate, 1.7 grams of benzoic acid were added. Although permanganate was used to complete the oxidation, the results were low by 0.339 %. The Kjeldahl-Wilfarth process gave the best results with alkaloids. Quantitative results could not be obtained with pyridine, quinoline and cinchonine. Asboth used a solution of 350 grams of Rochelle Salt and 300 grams of sodium hydroxide in 1 liter of water in his distillations, in order to keep metallic oxides in solution.

Ulsch (22) introduced platinic chloride as a catalyser: his charge consisted of 1 gram of substance, 0.05 gram of cupric oxide, 5 drops of platinic chloride solution, which contained 0.04 gram of platinum in 1cc., and 20cc. of a solution of 200 grams of phosphoric anhydride in 1 liter of pure, concentrated sulphuric acid. This mode of digestion is more rapid than that with mer-

curic oxide; the digestion is finished when the solution takes on a pure green (not a yellow-green) color. Oxidation with permanganate is entirely omitted. Analyses are given of the nitrogen content of a number of substances of both animal and vegetable origin.

Jodlbauer (23) improved the process of Asboth for nitric nitrogen and combined with it the method of Ulsch. He replaced benzoic acid by phenol, which more readily yields nitro derivatives. Stannous chloride was first used to reduce nitrophenol to aminophenol, but did not act with sufficient energy, while zinc dust gave excellent results. Platinic chloride was used as the catalyser. From 0.2 to 0.5 gram of potassium nitrate, or the corresponding amount of another nitrate was digested for 4 hours with 20cc. of concentrated sulphuric acid, 2.5cc. of phenolsulphonic acid (50 grams of phenol dissolved in sufficient concentrated sulphuric acid to yield 100cc. of solution), 2 to 3 grams of zinc dust and 5 drops of platinic chloride solution of such strength that 1cc. contained 0.04 gram of metallic platinum. Addition of 4 grams of phosphoric anhydride to a charge reduced the period of digestion to two hours.

The Association of Official Agricultural Chemists have modified both the Kjeldahl and Gunning methods to include the nitrogen of nitrates. Salicylic acid is added to form a nitro compound, which is reduced by means of zinc dust or sodium thio-sulphate. The use of the latter reagent was first recommended by Förster (24).

Sherman (25) finds that a loss of nitric nitrogen always occurs whenever much chloride is present with the nitrate. A yield of 99.6% of the total nitric nitrogen is obtained by the official modified Kjeldahl method, if the solution of salicylic acid in sulphuric acid be cooled, added to the material and permitted to stand in contact with the same for two hours at room temperature, with frequent shaking. Zinc dust is then added, heat is applied, and the rest of the process is carried out as officially directed. The official modified Gunning method yielded but 97.8% of the total nitric nitrogen, although the acid mixture was cooled, the thiosulphate was added slowly and with cooling and shaking, and the digested material was boiled for some time after it became colorless.

Kulisch (26) determines the nitrogen content of wine,

must and yeast by digesting with metallic mercury and a mixture of equal volumes of concentrated and fuming sulphuric acid, which contains 100 grams of phosphoric anhydride in each liter. Must contains much sugar, which should be fermented by addition of so slight a quantity of yeast culture that the nitrogen content of the latter may be neglected; the fermented liquid is digested in the usual way.

The determination of the nitrogen content of coal has been studied by Schmitz (27) and Lord (28). Schmitz digests from 0.8 to 1.0 gram of coal with 1 gram of mercuric oxide and 20cc. of concentrated sulphuric acid for from 2 to 3 hours. He digests coke samples for 1 hour with 1 gram of mercuric oxide and 20cc. of concentrated sulphuric acid, then adds another gram of mercuric oxide in portions and 2 grams of finely powdered potassium permanganate in small portions. Lord digests 1 gram of coal with 30cc. of concentrated sulphuric acid and about 0.65 gram of metallic mercury. "The digestion was continued for about three-quarters of an hour after the oxidation was apparently complete, the total time being about three hours."

Arnold (29) studied the action of a mixture of sucrose, benzoic acid, cupric sulphate and mercury, with and without the addition of phosphoric anhydride, in the digestion. With the following charge:

0.5 gram substance
1.0 gram mercury (metal)
0.5 gram cupric sulphate (anhydrous)
2.0 gram phosphoric anhydride
1.0 gram sucrose
2.0 gram benzoic acid
20. cc. concentrated sulphuric acid,

a period of 60 to 80 minutes was required for digestion. Excellent results were obtained in determining the nitrogen content of alkaloids, inorganic nitrates, nitro compounds, and cyanogen derivatives. Equally good results were obtained when phosphoric anhydride was omitted from the charge, provided the period of digestion was lengthened to 3 to 4 hours Pyridine and quinoline derivatives, azo compounds and inorganic nitrites gave low-values, even when oxidation by chromic acid or permanganate was resorted to, when the quantity of sucrose or of benzoic acid

was increased, or when benzoic acid was replaced by phenols, sulphonic acids or cellulose.

Gunning (30) recommends the digestion of 0.5 to 1 gram of substance with 20 to 30cc. of a solution of one part of potassium sulphate in two parts of ordinary sulphuric acid, until a colorless solution is obtained, requiring from one-half to two hours. He points out that acid potassium sulphate forms and acts upon the nitrogenous compound during the digestion exactly as would sulphuric acid heated under pressure above its boiling point. In the older methods sulphur trioxide might escape; here it is fixed and only water may escape; the sulphuric acid is concentrated, not weakened during the digestion. Gunning applied the method with success to such substances as morphine, antefebrin, peptone, bread, beer, milk and linseed cake.

Arnold and Wedemeyer (31) combined the Arnold and Gunning methods. They used:

0.5 gram substance
15. to 25 gram potassium sulphate
1. gram mercuric oxide
1. gram cupric sulphate
30. to 50. grams sulphuric acid,

and succeeded in converting into ammonia the nitrogen content of a number of compounds with which all other modifications of the Kjeldahl method are unavailable, e. g. quinoline and pyridine compounds, provided the bodies in question be non-volatile below the boiling point of sulphuric acid. When several nitrogen atoms are present in the heterocylic ring, the ease or difficulty of converting the total nitrogen content into ammonia may depend upon whether the nitrogen atoms be adjacent to or distant from each other. The former class of compounds seems to be more difficult to convert into ammonia, as is shown by experiments on members of the pyridazin, pyrimidin, pyrazin, quinazolin, cinnolin, quinoxalin, pyrazol and pyrazolin groups. In general, if the simple Kjeldahl treatment yield a lower percentage of nitrogen in a compound than does this modification, then nitrogen is contained in the ring. Certain determinations made by this method on antipyrine show that one at times may obtain concordant results and, therefore, apparently correct analyses by preserving the same conditions, while in reality the results are too low. These investi-

gators noticed that, if granulated zinc be replaced by two to three grams of zinc dust of known nitrogen content in the distillation, the use of potassium sulphide is unnecessary.

Winton, Ogden and Mitchell (32) applied the method of Arnold and Wedemeyer in determining the nitrogen content of both white and black peppers, and of their ether extract. They direct that—

1 gram substance
1 gram cupric sulphate
1 gram red mercuric oxide
15 to 18 grams potassium sulphate
25 cc. sulphuric acid

be heated gently until foaming ceases, then boiled from 3 to 4 hours. Before making alkaline in the distillation, 50cc. of potassium sulphide solution are added. Pure piperine gave results correct to within a tenth of one per cent.

Krüger (33) introduced potassium bichromate as the oxidizing agent in the digestion. From 0.2 to 0.8 gram of substance is dissolved in 20cc. of concentrated sulphuric acid with the aid of gentle warming, if necessary. After the solution has cooled, finely powdered bichromate is added in portions of 0.5 gram until 0.5 gram has been added in excess of the quantity theoretically required for complete oxidation of the substance. If carbon dioxide be evolved, even in the cold, addition of further quantities of bichromate must be deferred until the gas evolution ceases. Otherwise the entire quantity of bichromate may be added at once. The flask is next placed in a cold water bath, which is then heated. When the water boils and all the bichromate has dissolved, the flask is heated for ten minutes, with frequent shaking, upon a wire gauze, over a small flame, which need but touch the gauze. The end of the operation is recognized by the pure green color of the solution and the cessation of the evolution of gas. Frequently toward the end of the process chromic salts separate and cause the liquid to bump. Krüger states that the method yields good results with members of Dafert's first class of compounds (9). Several experiments on members of Dafert's second group lead to negative results, although the application of the method to this group is still a field for research.

Dyer (34) gently heats 0.5 to 5.0 grams of material with 20cc.

of strong sulphuric acid and a single drop of mercury until initial vigorous action has ceased, then gradually increases the heat during a period of 10 to 15 minutes, until brisk boiling begins. Ten grams of potassium sulphate are added and digestion is continued for 30 to 60 minutes when the contents of the flask become clear and colorless. For nitrates the use of phenol or, preferably, salicylic acid, zinc dust and mercury is recommended. Results are given of the analysis of a large number of aliphatic and aromatic compounds as well as cyanogen derivatives and alkaloids. Sucrose and zinc dust aided in the reduction of many refractory compounds.

Riviere and Bailhache (35) report the result of certain experiments designed to shorten the time required for decolorization with sulphuric acid in the digestion. Various substances, such as iron sulphate, vanadic, boric, molybdic and arsenic acids, were used to raise the temperature of the sulphuric acid, but in each case where the results were correct the process was too slow. Substitution of phosphoric acid for sulphuric acid yielded unsatisfactory results, even when maganese dioxide and phosphate were added to the charge. Ferric oxide and phosphoric acid gave correct results; however, the method is slower and more unpleasant than that of Kjeldahl. The only objection to the Gunning method is the relatively long time required with some substances, such as horn, for complete conversion of the nitrogen into ammonia. In the Kjeldahl method loss of nitrogen occurs if a great excess of mercury be used, and the mercury must be precipitated before distilling. Correct results were obtained with the greatest speed by digesting with sulphuric acid and 1 to 2 grams of sodium pyrophosphate for from 1 to 2 hours.

Dakin (36) directs that the substance be heated with the ordinary mixture of potassium sulphate and sulphuric acid to thorough disintegration, then allowed to cool below 100°C. A few grams of potassium persulphate are added and heating is resumed; vigorous evolution of oxygen occurs, and the black solution becomes clear. If the reaction appears incomplete, heat further, cool and add more persulphate. The persulphate must not be added to the liquid at too high a temperature; otherwise the salt will decompose too rapidly and proper oxidation will not occur. The function of the persulphate is twofold; it acts as an oxidizer and at the same time strengthens the sulphuric acid. Good results were ob-

tained more quickly with difficulty decomposable bodies like acetanilide, sulphanilic acid and the alkaloids by this method than by other methods. Dakin sums up: "It would appear that in the case of substances which are difficult to completely decompose in the ordinary way, potassium persulphate will find a useful application."

Recently the Gunning method has been modified by addition of a slight quantity of cupric sulphate to hasten the digestion. The Association of Official Agricultural Chemists (37) are considering the modification of the official method by permitting the addition of 0.1 to 0.3 gram of the crystallized salt. Hawk (38) reports that nitrogen is always lost whenever more than 0.2 gram of cupric sulphate is used in a digestion.

EXPERIMENTAL WORK ON ANTIPYRINE.

But one series of determinations of the nitrogen content of antipyrine—dimethylphenyepyrazalon—by any modification of the Kjeldahl method is to be found in the literature. Arnold and Wedemeyer (31) obtained the following results by their method:

Weight of Antipyrine used in grams.	Period of Digestion.	Per cent. of Nitrogen obtained.
0.7075	2 1/2 hours	9.6
0.6221	1/2 hour	9.69
0.658	5 hours	12.90
0.4356	2 hours	9.52

In the last experiment potassium permanganate was used for final oxidation. The results were not bettered by prolonging the digestion for 10 to 15 hours, or by subsequent oxidation with permanganate, barium dioxide, lead dioxide, or by the addition of phosphoric anhydride. A three to six fold increase of the cupric sulphate or mercuric oxide caused a loss of nitrogen. These results are considerably below the theoretic per cent., which is 14.89.

In the following experiments Jena flasks of 500cc. capacity were used for both digestion and distillation. The digested contents of each flask were dissolved in 200cc. of distilled water; a little granulated zinc was added, and an excess of concentrated sodium hydroxide solution (usually 100cc.) was poured in so that it sank beneath the solution of digested material. The flask was

connected with a safety bulb and a block tin condenser, and then the contents of the flask were mixed by shaking. To the lower end of the condenser was attached a piece of glass tubing of the same bore as the tin tube, for experience has shown that even acid of the dilution used will act upon tin and thus introduce an appreciable error. This glass tubing dipped beneath the surface of a measured quantity of $\frac{N}{10}$ sulphuric acid during the distillation proper, which was continued until bumping began, usually from 40 minutes to an hour. The Erlenmeyer flask, which contained the distillate, was then lowered so that the tubing was above the liquid, and the distillation was continued for 10 minutes, when the exterior of the tube was washed off into the flask and the contents were titrated with $\frac{N}{10}$ sodium hydroxide, using Grübler's congo red as an indicator. Whenever mercuric oxide was used in the digestion, the potassium sulphide solution was added and mixed by shaking before addition of the zinc and alkali. During several digestions, e. g. those according to Jodlbauer, and Riviere and Bailhache, it became necessary to add a slight amount of cupric sulphate to hasten the clearing of the liquid. Unless otherwise stated, the period of digestion was 5 hours. The antipyrine used was from two sources; one was a domestic brand, the other was the German "Löwenmarke." Both gave about the same percentage of nitrogen by the same method.

Antipyrine was digested with 0.7 gram of yellow mercuric oxide and 30cc. of concentrated sulphuric acid for 5 hours. No permanganate was used.

0.5235 gram antipyrine gave 11.52% N.
0.5224 gram antipyrine gave 11.52% N.

Samples were digested as above, and final oxidation was made with permanganate.

Permanganate was added to the hot digested material, which was again heated strongly.

0.5032 gram antipyrine yielded 10.22% N.
0.5038 gram antipyrine yielded 11.48% N.

The flask and its contents were cooled, permanganate was added, and heat was again applied.

0.5030 gram antipyrine yielded 9.90% N.
0.5124 gram antipyrine yielded 10.21% N.

Permanganate was added to the warm liquid, which was not again heated.

0.5201 gram antipyrine yielded 11.61% N.
0.5103 gram antipyrine yielded 11.87% N.

A saturated solution of permanganate in concentrated sulphuric acid was used as recommended by Czeczetka. However, use of a tap-funnel was replaced by a more convenient and less dangerous procedure. The solution in sulphuric acid was poured from a beaker down the side of the flask, then mixed by shaking with the cold solution which had been digested with mercuric oxide.

0.5161 gram antipyrine gave 12.46% N.
0.4888 gram antipyrine gave 12.31% N.
0.4557 gram antipyrine gave 11.97% N.
0.4581 gram antipyrine gave 11.99% N.

Samples were digested with 0.7 gram of crystallized cupric sulphate and 25cc. of a solution of 25 grams of phosphoric anhydride in 100cc. of concentrated sulphuric acid according to Wilfarth.

0.5074 gram antipyrine gave 9.62% N.
0.5037 gram antipyrine gave 9.80% N.

Wilfarth's newer method was also followed. Antipyrine was digested with 0.7 gram of mercuric oxide, 18cc. of concentrated and 12cc. of fuming sulphuric acid.

0.5076 gram antipyrine gave 11.70% N.
0.5029 gram antipyrine gave 11.61% N.

The charge directed by Jodlbauer was used with the addition of 0.2 gram of crystallized cupric sulphate.

0.5259 gram antipyrine gave 10.75% N.
0.5091 gram antipyrine gave 11.16% N.

A sample of antipyrine was permitted to stand over night in contact with 1 gram of salicylic acid and 30cc. of concentrated sulphuric acid; then 5 grams of sodium thiosulphate were added and heat was applied for five minutes. Ten grams of potassium sulphate and 0.2 gram of cupric sulphate were added and the digestion was continued for 5 hours.

0.5010 gram antipyrine yielded 12.11% N.

Two determinations were made by the original method of Arnold with the following charge:

1.1 gram mercuric oxide
0.7 gram crystalline cupric sulphate
2.0 gram phosphoric oxide
1.0 gram sucrose
2.0 gram benzoic acid
30. cc. concentrated sulphuric acid.

0.5216 gram antipyrine yielded 10.12% N.
0.5406 gram antipyrine yielded 10.07% N.

The official Gunning method required 5 hours to produce a clear solution; digestion was continued for an extra hour with this result:

0.5011 gram antipyrine gave 12.26% N.
0.5043 gram antipyrine gave 12.68% N.

The official Gunning method, modified by addition of cupric sulphate, was also tried.

With 0.1049 gram cupric sulphate
0.5026 gram antipyrine gave 11.48% N.
0.2003 gram cupric sulphate
0.5234 gram antipyrine gave 11.24% N.

When the method of Arnold and Wedemeyer was tried with a charge of 1 gram each of mercuric oxide and cupric sulphate, 16 grams of potassium sulphate and 30cc. of concentrated sulphuric acid,

0.5650 gram antipyrine gave 10.70% N.
0.5025 gram antipyrine gave 10.43% N.

The bichromate process of Krüger produced the lowest results of the series.

0.2341 gram antipyrine yielded 2.45% N.
0.5053 gram antipyrine yielded 1.57% N.

Dyer's process was applied using 30cc. of concentrated sulphuric acid and substituting 0.7 gram of mercuric oxide for metallic mercury.

0.5097 gram antipyrine yielded 11.69% N.
0.5169 gram antipyrine yielded 11.79% N.

In digesting according to Riviere and Bailhache, 30cc. of concentrated sulphuric acid, 2 grams of sodium pyrophosphate and 0.1 gram of cupric sulphate were used.

0.4706 gram antipyrine yielded 13.47% N.
0.4899 gram antipyrine yielded 13.20% N.

Weighed samples of antipyrine were allowed to stand over night with 5 grams of stannous chloride and 30cc. of concentrated sulphuric acid. Heat was then applied for 10 minutes; 10 grams of potassium sulphate and about 0.1 gram of cupric sulphate were added, and the digestion was continued for 5 hours.

0.4380 gram antipyrine gave 12.62% N.
0.4768 gram antipyrine gave 12.87% N.

An experiment was made using lead peroxide as the oxidizing agent; 0.5104 gram of antipyrine, 8.5 grams of the peroxide and 30cc. of concentrated sulphuric acid were digested for 5 hours. Only 10.20% of nitrogen was obtained.

When the following determinations according to Dakin were made, the potassium persulphate added to each flask was accurately weighed and due allowance was made in the calculation for the nitrogen content of the salt.

0.5256 gram antipyrine gave 12.21% N.
0.5074 gram antipyrine gave 12.33% N.

Sodium peroxide was substituted for the potassium persulphate with this result:

0.5108 gram antipyrine gave 13.25% N.

CONCLUSIONS.

Antipyrine has been digested in sulphuric acid solution with various combinations of the following reagents:

Catalysers—Cupric sulphate, mercuric oxide, platinic chloride.

Oxidizing Agents—Lead dioxide, sodium peroxide, potassium persulphate, potassium dichromate.

Reducing Agents—Sodium thiosulphate, stannous chloride, sucrose, phenol, organic acids.

Compounds which elevate the boiling point of the solution—Phosphoric anhydride, potassium sulphate, sodium pyrophosphate.

In no case has the theoretic per cent. of nitrogen been obtained;

the lowest values were obtained by use of potassium dichromate, the highest results by use of sodium peroxide, or of sodium pyrophosphate and cupric sulphate. The series of results obtained by digestion of antipyrine with mercuric oxide with and without subsequent oxidation by means of potassium permanganate are of interest. When heat was applied after the addition of permanganate, a lower percentage of nitrogen was obtained than when no permanganate was used. On the other hand, when permanganate was added and the digested material was not again heated, a higher percentage of nitrogen was obtained than when the use of permanganate was omitted.

The low values obtained are due either to incomplete oxidation of the antipyrine to ammonia and oxides of carbon or to escape of nitrogen in the elementary state. Since antipyrine-p-sulphonic acid exists, and since antipyrine also possesses the properties of a mono acid base (39), it must be retained in solution by the sulphuric acid and cannot escape from the flask unchanged during the digestion.

The absolute method of Dumas may be applied to antipyrine with success as is shown by the following determination made in the course of this investigation:

0.4319 gram of antipyrine gave 57.3cc. of nitrogen gas, which was measured at 25.6°C. when the pressure of the atmosphere was 761.0 m.m. of mercury. The percentage of nitrogen was 14.73, while the theory calls for 14.89%.

I wish gratefully to acknowledge my indebtedness to Dr. Harry F. Keller, at whose suggestion this thesis was written, for the kindly interest he has taken in my study of chemistry, both as an undergraduate and as an alumnus of the Central High School, and for the inspiration which his lectures have ever been to me.

I also desire to thank Dr. M. E. Pennington for aid and valuable suggestions in the preparation of this paper.

BIBLIOGRAPHY.

1. Zeitschrift für analytische Chemie, XXII-366.
2. Chemiker Zeitung, VIII-432.
3. Zeitschrift für physiologische Chemie, VIII-200.
4. Archiv. für die gesammte Physiologie, XXXV-454.
5. The same, XXXVI-102.

6. Zeitschrift für analytische Chemie, XXIII-532.
7. The same, XXIV-453.
8. The same, XXIV-454.
9. Landwirtschaftl Versuchsstationen, XXXIV-514.
10. Monatshefte für Chemie, VI-63.
11. Zeitschrift für analytische Chemie, XXIV-199.
12. The same, XXIV-388.
13. The same, XXV-155.
14. Chemiker Zeitung, IX-1357.
15. Chemisches Centralblatt (3), XVI-17.
16. The same (3), XVI-113.
17. Bureau of Chemistry, U. S. Department of Agriculture, Bulletin 107-6.
18. Chemical News, LII-162.
19. Chemiker Zeitung, IX-1501.
20. Journal of the American Chemical Society, VII-108.
21. Chemisches Centralblatt (3), XVII-161.
22. The same (3), XVII-375.
23. The same (3), XVII-433.
24. Zeitschrift für analytische Chemie, XXVIII-422.
Bureau of Chemistry Bulletin 107-7 and 8.
25. Journal of the American Chemical Society, XVII-567.
26. Zeitschrift für analytische Chemie, XXV-149.
27. The same, XXV-314.
28. U. S. Geological Survey Professional Paper, 48-186.
29. Zeitschrift für analytische Chemie, XXVI-249.
30. The same, XXVIII-188.
31. The same, XXXI-525.
32. Twenty-second Annual Report of the Connecticut Agricultural Experiment Station, 190.
33. Berichte der deutschen chemischen Gesellschaft, XXVII-609.
34. Journal of the Chemical Society, LXVII-811.
35. Analyst, XXI-267.
36. Journal of the Society of Chemical Industry, XXI-849.
37. Bureau of Chemistry Circular, 38-1.
38. Journal of the American Chemical Society, XXIX-1634.
39. Beilstein Handbuch der Organischen Chemie. Dritte Auflage, Ergänzungband, IV-326; IV-509; and IV-737.

THE Maschinenbau-Actien-Gesellschaft, Hanover, Germany, has now delivered the 5000th locomotive built at its works, and a summary is published of the work done in the locomotive department since the works were founded, in 1835. Of the 5000 locomotives constructed 1100 were for railroads outside of Germany, of which 241 went to Russia, 115 to Roumania, Japan coming next with 93, and 14 for the Argentine, the remainder being divided between European and Asiatic countries, and six to Chile. The especially interesting remark is made that none of these engines was sent to the United States.—*Iron Age.*

USE OF CROSS-TIES IN 1906.

The Forest Service at Washington estimates that the steam and street railroads of the country used in 1906 for new track and renewals more than 100,000,000 cross-ties. The average price was forty-eight cents. Oak furnished more than 44 per cent., and the Southern pines, which rank second, about one-sixth. Ten per cent. of the ties purchased were treated with preservatives. In the United States, estimating 2800 ties to the mile, there are over 800,000,000 ties in service. Cedar ties last eleven years, spruce ten years, red wood nine years, but these woods are not generally available, and they lack the desired weight and hardness. Of tie timbers in general use—chestnut, white oak, tamarack, spruce and Douglas fir—the average life is but seven years. A treated tie, with equipment to lessen wear, will last fifteen years. It is estimated that to maintain each tie now in track two trees must be growing.

TRANSVAAL GOLD PRODUCTION.

The gold production of the Transvaal in October, while not the highest monthly output on record, approached it very nearly, in spite of the repatriation of a number of Chinese laborers. It was claimed that this loss of men would seriously cripple several of the mines, but such a result is not yet apparent in the returns. This October production brings the total gold yield of the Transvaal for the ten months of this year up to $109,924,238. No considerable changes, either increase or decrease, can be expected in November and December, so that the total for 1907 may be fairly estimated at nearly $133,000,000. This will be an increase of $13,391,000 over the total for 1906; and it will be very nearly one-third of the probable gold production of the world in the present year.—*Eng. and Min. Jour.*

REPORT ON COAL PRODUCTION.

The United States Geological Survey announces the publication of statistics on the production of coal in 1906, in the form of an advance chapter from "Mineral Resources of the United States, Calendar Year 1906."

This report, prepared by E. W. Parker, the statistician in charge, exhibits primarily the details of quantity and value of coal produced in 1906, gives comparisons with previous years, and includes also statements regarding the labor employed, production per man, number of days worked, length of working day, use of mining machines and tonnage produced by them, casualties reported by mine inspectors, and all other matters of interest connected with the mining and marketing of coal. Appended to the report is a list of United States Geological Survey publications relating to coal, comprising about one hundred titles classified by States.

The chapter is now ready for distribution and may be obtained free of charge by applying to the Director, U. S. Geological Survey, Washington, D. C.

Section of Physics and Chemistry.

(Stated meeting held Thursday, April 23d, 1908.)

Standardization Apparatus For Measuring Volts, Amperes and Watts.

By E. F. Northrup, Ph.D.

The developments made in refined electrical standardization apparatus are in answer to a general demand. The desire for accurate electrical measurements is a consequence of the vast developments in manufactured electrical power. The extent and increase in the development of power is indicated by the coal consumption in the United States. In the decade of 1876 to 1885, 848 million tons were consumed; in the decade 1885 to 1895, 1586 million tons, or an increase of 87%, were used, and in the decade ending 1905, the coal consumption was 2833 million tons, or an increase of 78% over the previous decade. The increase in manufactured power, thus indicated, denotes a growing change in man's manner of living not less marked, perhaps, than was brought forth by the advent of fire or of iron. Success whets the appetite and the demand of the age grows to get still more power; moral, money, physical. Of the power manufactured, a continually increasing proportion is converted into and sold as electrical power. This electrical power has become a great commodity of exchange. In the transactions, whereby money power is given for electrical power, it is necessary to measure the barter as well as the exchange, and justice can exist only in proportion as the commodity sold is accurately measured. For every hundred dollars worth of power sold which is measured with an error of one per cent., one party to the transaction has a dollar more and the other party a dollar less than is his rightful due. There is an

ethical demand of the people for justice, and accurate means for measuring electrical power is needed to meet this demand.

All the apparatus actually used in measuring power, which is sold, must finally depend upon concrete standards, made equal to or multiples of the units of definition. The actual calibration of the commercial measuring instruments is accomplished by making use of Standardization Apparatus especially contrived for the purpose.

This apparatus must be reliable in registering quantities that are multiples of the units of definition. The units of definition must be embodied in the form of concrete standards which are maintained accurate through repeated comparisons with fundamental standards under governmental care and certified to by governmental authority. Justice in the sale of electrical power rests on the accuracy of commercial measuring instruments, the accuracy of these rests upon standardization apparatus, and the precision of this rests upon concrete standards certified to by the government.

The National Bureau of Standards at Washington supplies the instrument maker with the means of giving precision to this standardization apparatus, and the decisions of this Bureau have an ethical value not unlike that of the decisions rendered by a superior court of civil law.

Having noted the value and need of precision apparatus for standardizing commercial instruments, I shall discuss the present status of standardization apparatus used in the masurements of volts, amperes, and watts.

Electrical power is composite, being made up of the product volts and the amperes in phase with the volts. When the average power consumed in a given time is multiplied by the time the total amount of energy used is given. In a general way this integrated power corresponds to the total work done by the prime mover and constitutes the basis of charge when the power is sold. Hence, the commercial instrument for determining the proper charge to a customer is the watt-hour meter. But there are both scientific and practical considerations which make it necessary to measure separately the components of power, E. M. F., and current. In the case of direct currents, if either of the factors, volts or amperes, is maintained constant, the total energy is obtained from the integrated product of the two factors multi-

plied by the time and there is, therefore, relatively little use for indicating or integrating direct current wattmeters. With alternating currents, however, the case is different. Here the power is the product of the E. M. F. by the component of current in phase, and as the phase of the current is a shifting and unknown factor, it is necessary to use wattmeters to measure the power which automatically register or indicate the true and not the apparent power. If the wattmeters operate on a dynamometer principle, it is possible, but not convenient, to calibrate them with direct current by measuring the volts and amperes. If, however, they operate on the principle of induction meters they must be calibrated with alternating currents of the frequency with which they are to be used. This calibration is practically effected by comparing them with a standard indicating wattmeter which operates on the dynamometer principle. If the induction wattmeter is an integrating instrument, the calibration may still be made with an indicating standard wattmeter, by maintaining the power, used in the calibration, constant over a known period.

Whether the voltmeters, ammeters, and wattmeters operate on direct or alternating currents, in calibrating them it is always necessary to refer ultimately to direct currents or direct E. M. F.'s. If an induction wattmeter has been calibrated by means of an indicating wattmeter of the dynamometer principle, this instrument, if used as an ultimate standardization instrument, will have had its constant gotten with direct currents or E.M.F.'s.

Any line of standardization apparatus, which is complete for calibrating the instruments used in the commercial manufacture and sale of electrical power, will consist of instruments which will accurately measure D. C. and A. C. volts and amperes, and true watts in alternating current circuits.

Such apparatus, naturally, is classified into direct and alternating current standardization instruments. While the direct current apparatus will not operate on alternating currents, the alternating current apparatus may be used often with direct currents. But, it should be again noted that the constants of all alternating current instruments must be ultimately gotten, when needed, with direct E. M. F.'s or currents, and therefore no laboratory is equipped for making calibrations, which are independent of instrumental constants, unless it is supplied with direct current standardization apparatus.

The developments in electrical standardization apparatus are intimately associated with the names of Kelvin, Siemens and Clark. Kelvin's electrometers, electrostatic voltmeters, and current balances, Siemen's electro-dynamometer and Clark's standard cell employed in potentiometer methods, constituted for years the jury of standard instruments that sat in every well equipped laboratory. The electrostatic instruments of Kelvin could be calibrated with the absolute electrometer, but to convert the indications into electromagnetic measure required a knowledge of the ratio of the units in the electrostatic and electromagnetic systems. Hence, the great importance always attached to this determination. The Kelvin balances were calibrated with direct currents, these currents being measured with voltameters. From the theory of the Kelvin balances it was then assumed that they would serve to give the square root of the mean square value of an alternating current, irrespective of its wave form or frequency. The Siemen's dynamometers, like the balances, were constructed to measure volts, amperes, and watts, and their constants were obtained in the same manner.

The potentiometer, using the standard cell, starts with the E. M. F. of a particular chemical combination as the basis of measurement. The balances and dynamometers calibrated with voltameters start with Faraday's Law of Electro-chemical Equivalents as the basis of measurement. And the dispute is still on as to which is the best foundation to rest upon.

For many years great prominence was given to the tangent galvanometer as a standard instrument for the measurement of direct currents. This instrument, however, is now chiefly used for demonstration purposes, other and more convenient apparatus having taken its place as a standard instrument.

Perhaps there is nothing which more attests the greatness of the early investigators in the budding science of electrical measurement than the comparatively few changes and unimportant developments which have been made in recent years in electrical standardization apparatus for E. M. F., current, and power measurements. Time will not permit me to follow the development of the minor modifications and improvements which our commercial practice, rather than our scientific enquiry, have brought about in historical standardization apparatus. I shall give only in rapid review an outline description of the most modern forms

which this apparatus has taken, and take notice of those features which appear specially worthy of attention.

DIRECT CURRENT STANDARDIZATION APPARATUS.

The practical and the most precise calibration of all forms of direct current instruments is now effected by one method, and by one apparatus, which in its manifold external forms operates on essentially the same principle.

The potentiometer and the potentiometer null method has survived and developed into the simplest and most accurate means for making all direct current standardizations. The success of the method is largely due to the satisfactory precision and per-

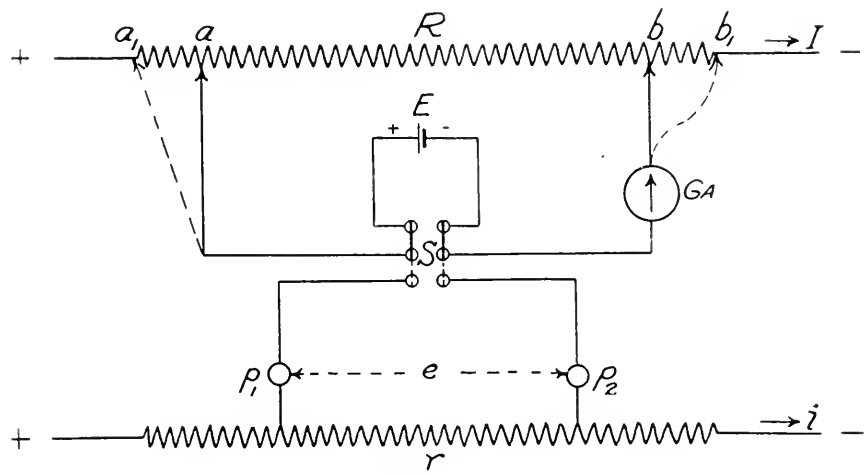


Fig. 1.

manence to be obtained in standard cells and to the reliability and the simplicity of the apparatus with which the method practically is carried out.

The principle of the method in its essential features is indicated in Fig. 1. A source of known E. M. F. and a galvanometer are first thrown in series in a circuit forming a branch to a circuit having uniformly distributed resistance, R. The galvanometer will show no deflection when the current, I, in the circuit is adjusted so that the potential between the points a, b, where the branch circuit is attached, is equal to that of the source of the standard E.M.F. By throwing, with the switch S, a source of unknown E.M.F., into the branch circuit, the value of this E.M.F. is given when the points a, b, are moved into the positions a_1, b_1,

where the galvanometer again gives no deflection provided the current, I, has not changed in the meantime. As R is assumed to be uniformly distributed the unknown E.M.F. is in the same ratio to the known E.M.F as the distance a_1 b_1 is to the distance a, b.

For the potentiometer method to be successful and accurate, means are provided for maintaining the current, I, constant through the resistance, R, during the measurement. The method is made convenient, rapid, and direct reading, by marking the positions taken by the points a_1 and b_1 directly in volts. The source of standard E.M.F. most suitable to use is the Weston Standard Cadmium Cell. This cell has an E.M.F. of 1.01 + volts at temperatures ranging from 10° C. to 25° C., so that no temperature corrections need be made. The cell will safely deliver a current of .0001 ampere.

The unknown source of E.M.F. may result from the drop produced by a large current flowing through a low resistance. When such is the case, if this resistance, r, between two potential points, p_1, p_2, is known, the value of any current flowing through such resistance is given by the ratio of the measured E.M.F. to the known resistance. Thus, the value of the current flowing through any instrument to be calibrated, which is in series with the resistance over which the potential drop is measured, is directly determined.

Or a direct source of E.M.F. may be obtained from storage cells and be many times as great as that of the standard cell. When such is the case, a so-called volt box is employed. By this device, a known decimal fraction of the total voltage, which does not exceed the E.M.F. of the standard cell, is carried to the potentiometer terminals and measured. D. C. Voltmeters are thus calibrated.

Or the source of unknown E.M.F. may be the feeble E.M.F. of thermo-couples, much used now in temperature determinations. When a thermo-couple is used with a galvanometer in series with it to measure its E.M.F., the E.M.F. is only indirectly measured, the galvanometer directly measuring the current developed by the thermo-couple. If the resistance of the entire circuit can be known and maintained constant, then the galvanometer can be made to measure the E.M.F. developed. When the potentiometer is used for measuring thermo-couple E.M.F.'s, these are given di-

rectly and are determined independently of the resistance in series with the thermo-couple, because at the moment of balance no current flows in the thermo-couple circuit. High precision is thereby given to a measurement that by other methods is but moderately accurate.

It will be noted that in all potentiometer null methods no instrumental constants enter into a measurement. The determinations, whether of E.M.F. or current are given in the form of direct comparison with standard E.M.F.'s and resistances. The possible precision and permanence of concrete standards of these two quantities is very great, accuracies of a 1/25% or better being entirely practicable in commercial practice.

The potentiometer adds to its high precision a very extended range. An instrument for commercial use, when supplied with suitable current standards and volt boxes, will measure currents from less than .00001 of an ampere to 6000 amperes by practically infinitesimal steps and E.M.F. from .0001 volt to 1500 volts in like manner, or much higher voltages, if resistances in volt boxes are constructed for the purpose.

On account of the fluctuating character of commercial voltages it is not always easy, in measuring these voltages, especially when applied to standard lamps in photometric work, to manipulate the sliding contacts of a potentiometer, and secure the exact balance of the galvanometer, required by the null method.

This consideration has led to the development of a type of potentiometer by Dr. H. B. Brooks, of the National Bureau of Standards, which is intermediate between a deflection and balance type of instrument.

The essential principle of this admirable instrument is that the bulk of the unknown voltage is measured by the potentiometer method and the small remaining departures from the exact value are indicated by a delicate millivoltmeter of the Weston type. Reference to a full description of this instrument may be found in the Bulletin of the Bureau of Standards, Vol. 4, No. 2, for January, 1908, p. 275.

The variety of forms which have been given the potentiometer by physicists and by instrument makers precludes even a cursory mention of the best of them. Broadly considered they may be grouped into high and low resistance potentiometers, according as the potentiometer circuit is made up of groups of resistance

coils without an extended slide wire and having a total resistance of several hundreds or thousands of ohms, or is made up of a few resistance coils of comparatively low resistance to give the coarse steps, and an extended slide wire to give the fine or infinitesimal steps in the adjustment of a voltage balance. The mechanical difficulties in the construction of the low resistance instrument are perhaps greater than in the high resistance type, but these difficulties having been met, the practical working is simple and the theoretical sensibility is greater.

The potentiometer shown in Fig. 2 is of the low resistance type. It has fifteen coils of five ohms each, giving fifteen steps of 1/10th volt each, and a circularly arranged stationary slide wire about

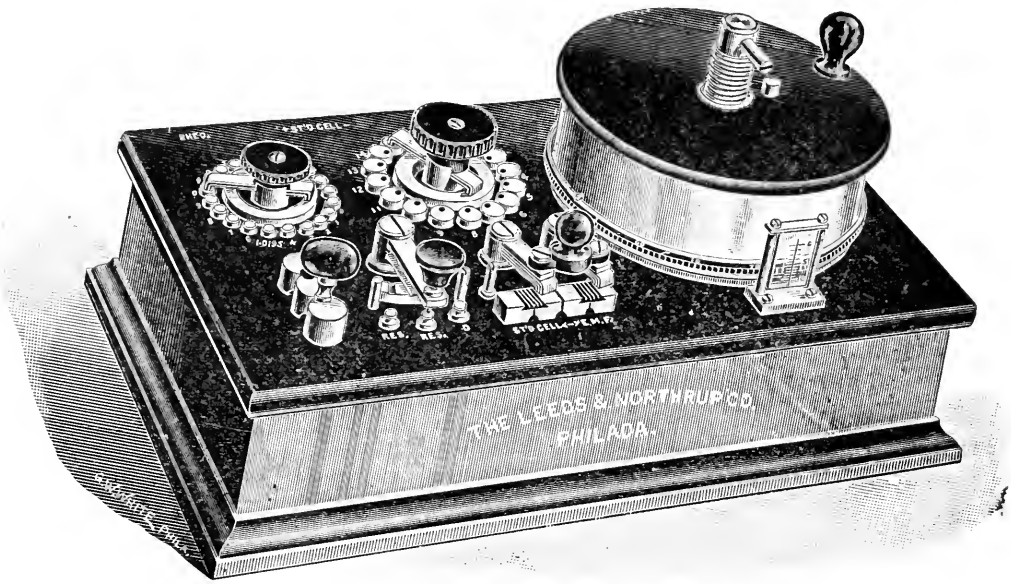


Fig. 2.

210 inches long and making eleven turns around a marble cylinder. Ten of these turns are equal to the resistance of one coil.

A travelling sliding contact moves over this wire and a scale reads directly in steps of .0001 volt. By means of a shunting device on the potentiometer wire each step given by the coils is made to equal .01 volt and the smallest divisions upon the scale, indicating the lowest steps, is made to equal .00001 volt. Means are also provided for quickly checking the current through the potentiometer circuit without losing or changing the setting obtained for a balance when measuring the unknown E.M.F. This type of instrument with its necessary accessories, consisting of a rheostat to regulate the current, current shunts, and volt boxes, storage cells

to furnish a steady current, and standard cadmium cell, makes an outfit which will cover every possible case of the calibration of commercial direct current instruments used to measure volts, current, and power.

The deflection type of potentiometer as realized in its commercial form and designed by Dr. Brooke, is illustrated in Fig. 3. This instrument covers in an exceptionally convenient manner the rapid voltage measurements that must be made in lamp photometry. It is likewise serviceable for all voltage measurements of moderate or high E.M.F. The measurements are made by setting the dials until the unknown E.M.F. is approximately balanced. The exact E.M.F. is then given at any instant by adding to or subtracting from the value of the E.M.F., indicated by the positions of the dials, the small E.M.F. indicated by the deflection of the millivoltmeter.

There are many foreign makes of potentiometers of deservedly high popularity, but in recent years this instrument has received a careful study and refined development in America. This development has been made in answer to the demand of capital invested in commercial measuring instruments which must be maintained in accurate calibration for correctly measuring the vast quantities of electrical power manufactured and sold. Where these instruments operate upon direct currents they can all be checked or calibrated with a potentiometer by which their indications are referred directly to standards of E.M.F. and resistance, which standards in turn may bear National Bureau certificates. Thus the possible standardization of all direct current commercial apparatus is on a most satisfactory basis, and it only requires legislative action and careful watching to insure that determinations are made to any required degree of commercial accuracy of all direct current power which is sold.

ALTERNATING CURRENT STANDARDIZATION APPARATUS.

Since the power in an alternating current circuit depends not only upon the volts and amperes in this circuit but also upon the phase relations between these two quantities, it is necessary, in standardizing an instrument which is to measure power, to be able to measure the volts and amperes and the phase relations between them; or to provide a standardizing instrument which meas-

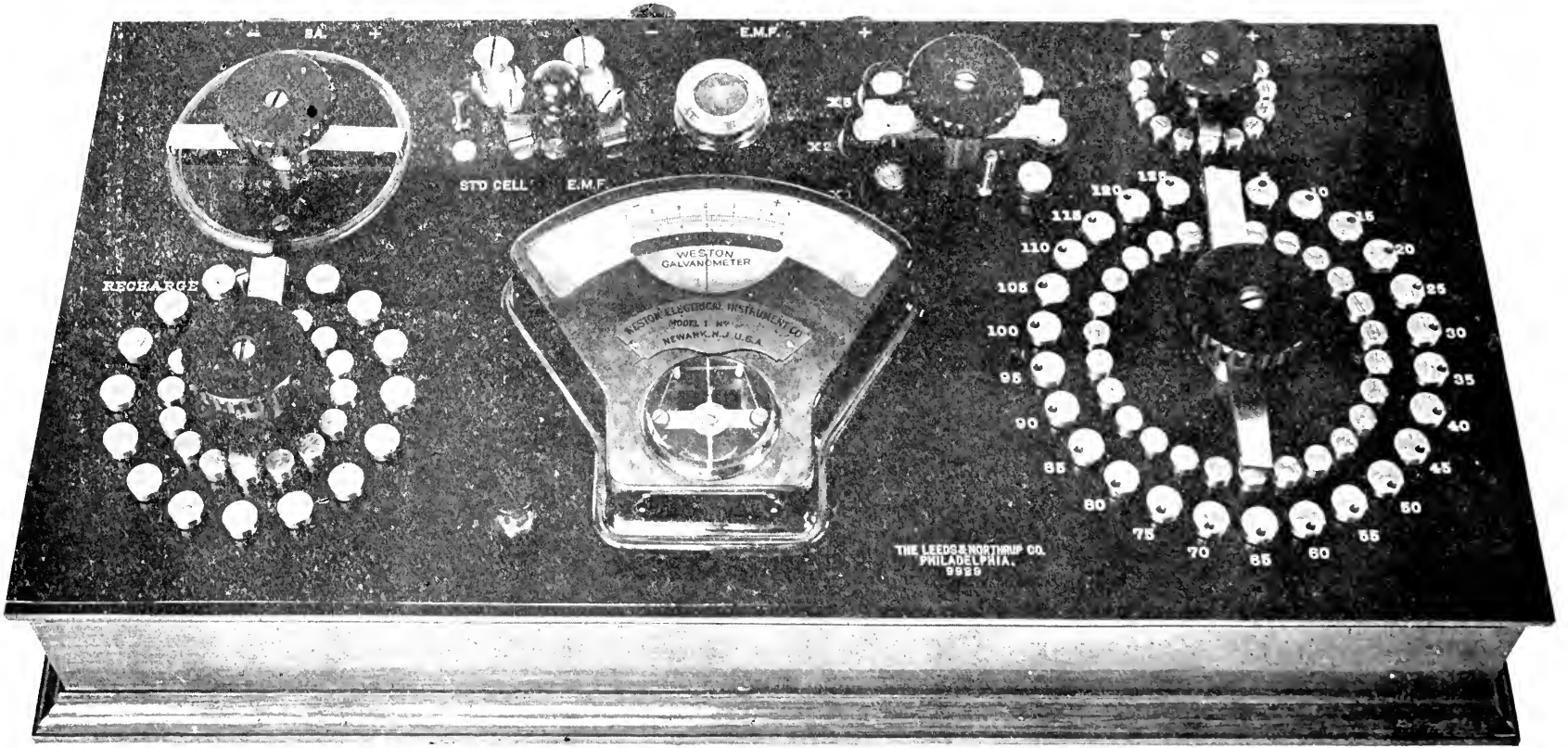

BA
E.M.F.
STD CELL
E.M.F.
RECHARGE
WESTON
GALVANOMETER
WESTON ELECTRICAL INSTRUMENT CO.
MODEL 1 No
NEWARK, N.J. U.S.A.
THE LEEDS & NORTHRUP CO.
PHILADELPHIA.
9929

Fig. 3.

ures true power independently of phase relations. As the phase relation can be determined practically only in the rare case of pure sine wave currents, the latter course is the practical one to adopt. A full line of alternating current standardization apparatus will consist then of instruments which will measure with high precision volts, amperes, and true watts. The range of measurements which must be provided for with these instruments is greater than in the case of direct current instruments. By means of potential and current transformers, alternating current power is furnished in the form of small currents and high pressures and large currents and low pressures. To cover the cases of actual practice instruments are required which will measure pressures up to tens of thousands of volts and currents to several thousands of amperes. On the other hand comparatively small E.M.F.'s and currents often need to be measured. In calibrating wattmeters of very large capacity it is generally necessary to be able to do this without actually developing electrical power, which is more than a small fraction of the power which the wattmeter under calibration will register. While the principles of accurate measurement of electrical power laid down by the early investigators, are sufficient to cover all modern requirements, the apparatus designed by them is inadequate for handling the extensive ranges of measurements now required to be made.

Thus Kelvin balances that will register 1000 amperes, which must pass through the copper ligaments supporting the swinging coils, become elaborate and costly instruments. It is not practical to construct a Siemen's current dynamometer to carry much over 500 amperes, and even such an instrument is costly to build. Furthermore, the inductive effects of large alternating currents are so great that grave errors, often too subtle to detect, are introduced by eddy currents in metal parts and in the coils of large-current instruments. To avoid both the cost and the danger of error in the use of heavy current standardization instruments, it is customary to resort to both potential and current transformation by means of iron-cored transformers to bring the volts and amperes within the ranges of the instruments of small or moderate capacity that are used and practical to build when constructed according to customary patterns. But this practice at once introduces into the measurements a new set of constants, namely,—the ratios of transformation of the transformers em-

ployed. If these ratios could be obtained accurately by calculation, and could be relied upon to remain constant with currents of different frequencies and wave forms, and if they were the same for 10% and 100% of full transformer loads, and if the iron in the transformers were not subject to a slow aging, and if the phase relations between the currents and the pressures could be determined and remained fixed, then, if all these demands of an accurate method could be assured, there would be no necessity of standardization apparatus of capacities exceeding 110 volts and five amperes.

Experimental investigations (See discussion by L. T. Robinson on "The Current Transformer" Proceedings of A. I. E. E., Vol. XXV, p. 727, September 28, 1906), however, show that for standardization purposes, transformers will not yield results that are satisfactory for the purpose, unless all their constants are determined experimentally under the conditions in which they are to be used. This determination necessitates, of course, standardization apparatus of large capacity.

The real problem then introduced by the manufacture and sale of large quantities of alternating current electrical power, is how to design and construct standard alternating current instruments to measure volts, amperes and watts, which shall cover, in the most efficient manner in regard to cost, a great range of measurements with high precision. Direct current measurements are now referred by the potentiometer method, directly to standards of E.M.F. and resistance, without the intervention of instrumental constants, which depend for their constancy upon the properties of materials, such as the elasticity of springs and the magnetization of steel. It is equally desirable to develop alternating current standardization instruments to operate upon principles that make them independent of instrumental constants; and for volts and current measurements this has been accomplished in an entirely satisfactory manner in the ways to be described.

The direct measurement of the square root of the mean square value of alternating current volts is simpler and easier than the same measurement of alternating currents of large value. The measurement resolves itself into two methods. In one the potential is measured by an electrometer calibrated with an absolute electrometer and converted into volts by the now accurately known value of v, the ratio of the electromagnetic to the electrostatic unit. In

the other the potential difference is determined by measuring the very small current which flows through a high and non-inductive ohmic resistance. This latter method is advocated as being probably the more accurate and better adapted to commercial requirements. The precision of the method depends upon winding a high ohmic resistance which is nearly free from inductance and capacity, so that reliance may be placed upon the practical coincidence in phase of the current through the resistance and the potential at its terminals. This result is easily gotten in the form of resistance here shown.

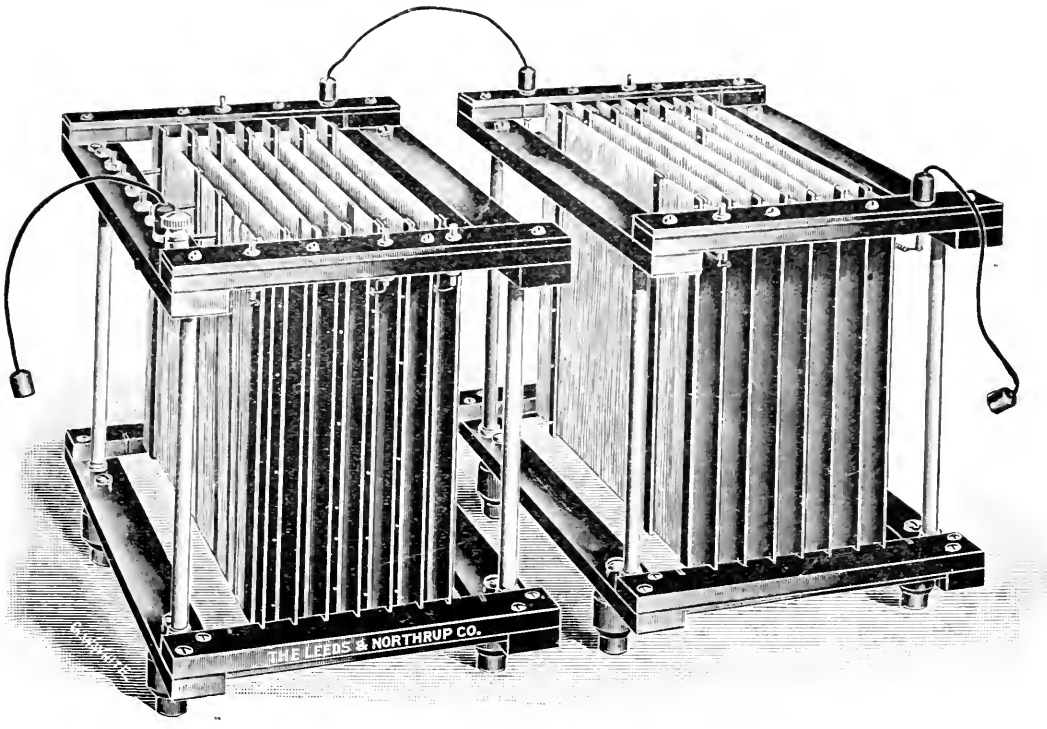


Fig. 4.

The wire used is manganin insulated with black enamel about .0002″ in thickness. This wire has a temperature coefficient not exceeding .00002 per degree Centigrade, and a resistance about twenty-eight times that of copper. The wire is wound with turns close together upon sheets of micanite 1/16″ thick. These sheets will safely dissipate ¼ watt per square inch of winding. On account of the high specific resistance of the wire and the manner of winding, these resistance cards have an exceedingly small capacity and inductance which may be entirely neglected in any alternating current measurements made for standardization purposes. The card units may be joined in series and mounted in

highly insulated frames and so give resistances to which tens of thousands of volts may be safely applied. The current flowing through them may be calculated on the basis of Ohm's Law. A measurement of this current at once gives the square root of the mean square potential at the terminals of any known section of this resistance. The resistance value is ordinarily adjusted so that with the potential applied the current will not exceed one-tenth of an ampere.

This small alternating current may be measured by a deflection instrument of the electro-dynamometer type or by a null method. If a dynamometer instrument is used this instrument should be calibrated shortly before it is used to have assurance that its instrumental constant has not changed. The dynamometer instrument may be calibrated on direct currents using a potentiometer for the purpose. As the swinging system of portable instruments of this type has but one coil the influence of the earth's field must be eliminated when making the calibration by reversing the current used in the calibration and taking the mean of the two readings as the true value. The calibration should be made over the entire portion of the scale used in the alternating current measurement, as the deflections cannot be relied upon to follow accurately the square law. A better type of electro-dynamometer for the purpose is one in which the swinging system consists of two light coils that make in reference to the earth's field an estatic combination. Such an instrument will then read the same on both direct and alternating currents, and it is unnecessary to reverse the former when calibrating the instrument.

In this method of measuring an alternating current voltage it is to be noted that a deflection of a moving system is read and reliance is placed upon the accuracy of the calibration of a scale and the maintenance of the constancy of the indications of the instrument. The directness and the simplicity of the potentiometer method employed with direct current calibration, therefore, is lacking. The accuracies are limited to a fifth or at best a tenth of a per cent. Instruments of the Siemen's dynamometer type and hot wire instruments might be substituted for the deflection electro-dynamometer, but both must be calibrated, and there is no gain in simplicity or precision.

It is highly desirable to be able to measure alternating voltages and currents by a null method, which at once eliminates all instru-

mental constants and which will place alternating current measurements upon the same basis as the potentiometer method places direct current measurements, namely, the effective value of an alternating voltage should be compared directly with the E.M.F. of a standard cell and, as is in the potentiometer method, the quantities measured should be given directly in terms of the value of a standard cell and values of resistances. In other words, to place the measurement of alternating current voltages and amperes upon the same satisfactory basis as the measurement of direct current voltages and amperes, a potentiometer method, employing in effect an alternating current potentiometer, should be used. To accomplish this end there has been designed certain null methods using an instrument which has been designated, the alternating current-direct current comparator. This instrument measures without the intervention of instrumental constants or quantities other than resistances and a standard cell, alternating current volts and amperes, and, where power can be expended in a non-inductive load, alternating current watts. As noted above, the measurement of alternating current voltages resolves itself into the accurate measurement of a small alternating current which flows through a highly non-inductive resistance. We may, therefore, introduce here a brief description of the A. C.-D. C. Comparator, and then explain the unimportant modifications in the method and apparatus to use the comparator for the direct measurement of large alternating currents up to a thousand or more amperes.

The complete instrument, together with a shunt, employed in the manner to be described for measuring large currents, is illustrated in Figure 5.

The differential system or wire holder is illustrated in Fig. 6. In its essentials the apparatus is an exceedingly sensitive instrument for detecting differences between two small currents and showing when they are equal. Its action is the same whether the currents be direct or alternating, consequently it can be used to show equality between small direct and alternating currents.

Referring to Fig. 7, A B and C D (also shown in Fig. 8), are two small wires of equal length, diameter and resistance, stretched as shown, about 5/32″ apart and pulled back at their middle point by a cross-piece resting on each wire. A spring attached to this cross-piece keeps a constant tension on the two wires. A

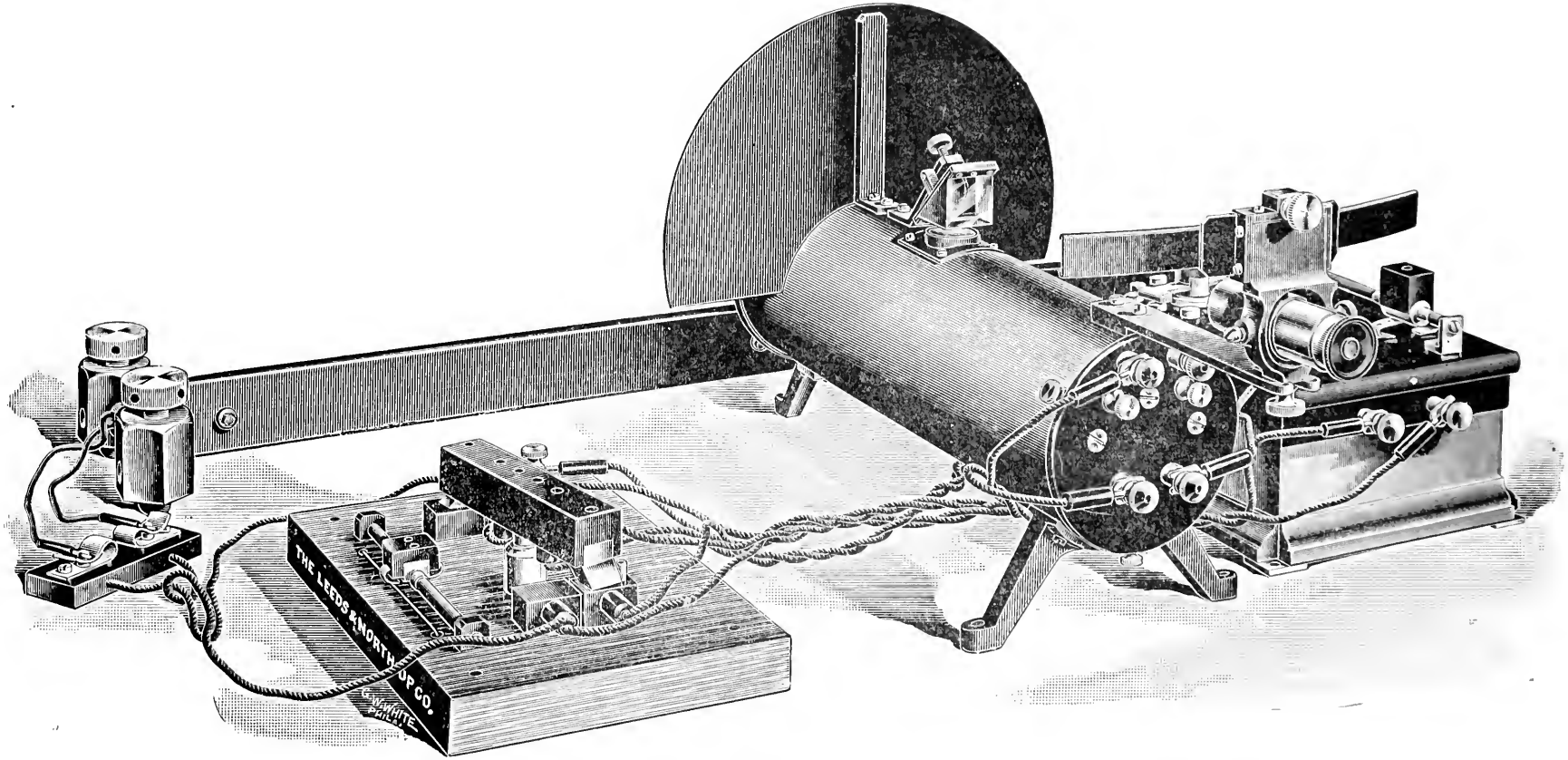


Fig. 5.

mirror is mounted on the cross-piece. Fig. 8, which is a cross section across the wires, and the cross-piece makes clear the construction of this part of the apparatus. It will be evident that if one wire elongates more than the other, the mirror will tilt, and a very slight tilting can be observed by the telescope and scale, in Fig. 6. As both wires will be influenced in the same way by external temperature changes, the apparatus will not be influenced by them. Equal currents flowing through both wires will cause

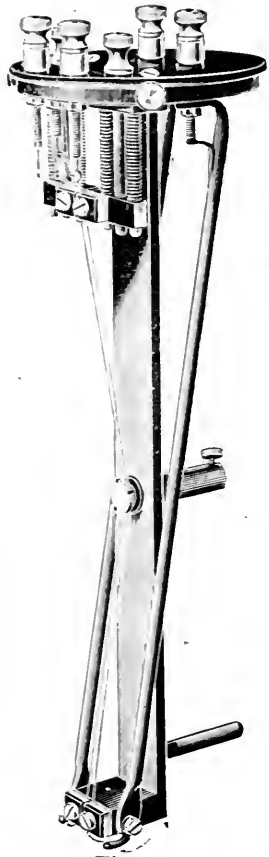


Fig. 6.

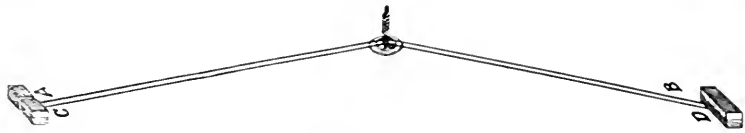


Fig. 7.

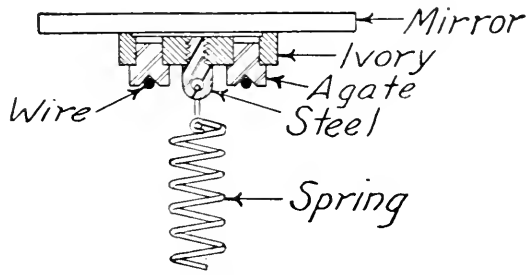


Fig. 8.

equal elongation and no deflection; but a slight difference in the current in the two will cause unequal elongation, due to heating, and a deflection.

The diagram, Fig. 9, shows how A. C.-D.C. Comparator may be used to measure the small current through the non-inductive high resistance, R_v, and, consequently, the voltage between A. C. mains.

S is a double-throw switch. When this switch is on "check," the two wires are in series with each other and are both traversed

by the current which can flow from the line through the non-inductive high resistance R_v. Under these circumstances, the comparator must be adjusted so as to show no deflection. With the switch at "test," exactly the same current will flow through the wire A B, as r^1, has the same resistance as C D and replaces it. By adjustment of rheostat r, the same current is made to flow through C D as will be shown by a balance. This current is read by an accurately standardized D. C. instrument Am, or better, by a potentiometer, which eliminates all instrumental constants. Calling this C, the E.M.F. across the A. C. Voltmeter will be $V = C R_v$.

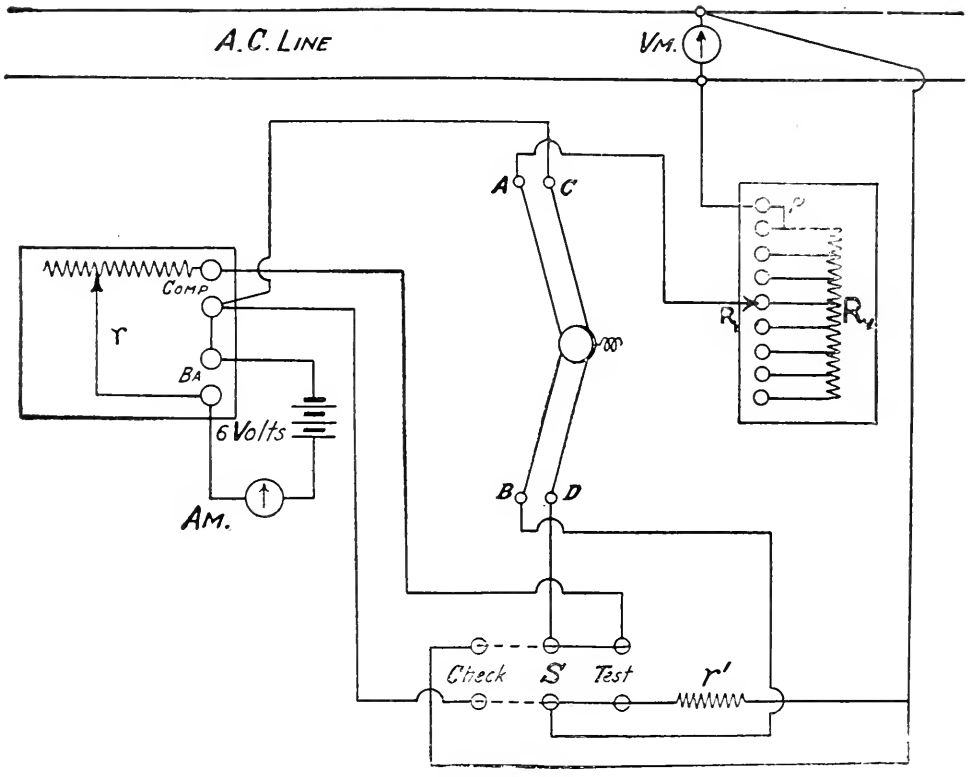


Fig. 9.

When it is required to measure larger alternating currents than can be carried by the wires of the comparator this may be accomplished by employing non-inductive shunts. These shunts must be designed to be highly non-inductive and independent of temperature changes. Both of these results are secured by building the shunts of sheet manganin—an alloy which has practically a zero temperature coefficient—and arranging the material in a non-inductive form as is illustrated in the shunt shown back of the in-

strument, Fig. 5. The simplified diagram, Fig. 10, shows the essentials of the theory of measuring large currents with the A. C.-D. C. Comparator.

A B and C D represent the two wires of the instrument; R is the non-inductive resistance through which flows the A. C. current to be measured; f^1 and h^1 are potential points on it, the resistance between which is accurately known. The lead resistances, ef and gh, are made equal to e^1f^1 and g^1h^1. S S are the two parts of a switch (separated in the diagram, but not in practice) by means of which the terminals of the wire C D may be connected either to e^1 and g^1 or e and g. V is an accurate D. C. voltmeter, or better, a potentiometer; r is a regulating rheostat and m a battery.

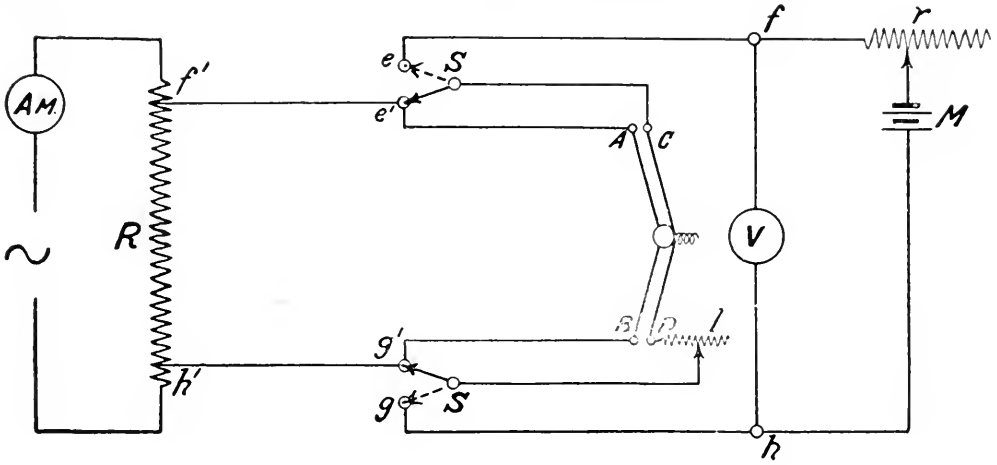


Fig. 10.

In making a measurement, the switch S is thrown so as to connect the two wires in parallel, then by means of the small rheostat l an adjustment is made until the comparator gives no deflection when the current, which is to be measured, flows through R. This adjustment of rheostat l may be neglected in all cases except when comparatively high resistance shunts are used. The switch is next moved so as to connect C D to the direct current side and r regulated until there is again no deflection. From the symmetry of the construction, it will be evident that the direct E.M.F. read on the instrument V will be the same as that across the points f^1 and h^1. Calling this v, the current through the Ammeter Am will be $\frac{V}{R}$ + the current which flows through the wire A B. The small portion of the current which flows through A B varies with v, but is determined for each instrument for all values

of v and may be expressed in the form of a curve called the function v curve, F (v). The complete formula for the current is then

$$C = \frac{V}{R} + F(v).$$

The resistances R are so chosen and the apparatus is so designed that for all measurements of current above six amperes v varies between the limits .2 and .6 volt, consequently, for the D. C. side, a single battery, rheostat and standard instrument for measuring up to .7 volt, is all that is necessary for the measurement of all ranges of alternating current above six amperes.

By means of slight modifications in the apparatus and shunts, currents from six amperes down to 1/20th ampere may be measured in like manner.

The above description shows that the A. C.-D. C. Comparator may be used as a companion instrument to the potentiometer and thus all voltages and currents both D. C. and A. C. can be measured directly in terms of a standard E.M.F. and resistances. The precision of the A. C. measurements may be made equally high throughout the range of measurements made if a sufficient number of high resistance units and low resistance shunts are at hand to maintain the sensibility of the comparator about the same, regardless of the volts or amperes being measured. Experience shows that this result is practically accomplished if a new resistance value and new low resistance shunt be used each time the voltage or current being measured is doubled in value.

For obtaining sufficient sensibility in large current measurements it is necessary to have the potential drop over the shunt equal to not less than .2 volt. Hence, a shunt to use in measuring 1000 amperes would have to dissipate at least 200 watts. This means that for large current values the shunts must have a large size and heavy construction which makes their cost considerable when 500 or 1000 amperes are exceeded. Outside of this consideration alternating current measurements of volts and amperes for calibration purposes are on nearly as satisfactory a basis as direct current measurements; for the directness of the A. C. measurements is nearly equal to that of the D. C. measurements, while the precision of the measurements is easily made equal to 1/10th per cent. or better.

To cover, however, the present commercial requirements where

the alternating current is used in electric furnaces, in electric welding and in power stations of large output, it is often desirable to be able to measure currents considerably exceeding 1000 amperes. In practice, these large currents would be measured with the aid of a series transformer. The ratio of the transformer would be computed and its small secondary current would be measured by an alternating current ammeter which could be accurately checked by any of the well known methods. The large primary current would then become known as accurately as the calculated ratio of transformation of the series transformer. A true and accurate value of the ratio of a series transformer cannot, however, be obtained by computation. The ratio should be obtained experimentally, under the conditions of frequency, wave form and load, in which the transformer is to be used to get an accurate determination of the heavy primary current from a precise measurement of the small secondary current. There is, therefore, need of a standardization instrument, of not excessive cost, which can be inserted directly in an alternating current circuit carrying any current over 1000 amperes, and which will measure this current with the same precision as small alternating currents are measured. The problem of measuring a very large alternating current with precision is a difficult one from a technical standpoint and has always heretofore involved the use of very expensive apparatus. The method of the A. C.-D. C., Comparator would make the measurement accurately, but the expense for the shunt would be large. To measure 10,000 amperes would require a shunt that would dissipate 2000 watts, and if this were air cooled in still air, it would have to have a superficial area of 28 square feet. The measurement might, however, be made practicable by using tubular shunts of manganin cooled with water circulating through them. A Kelvin balance for such a great current has been constructed and used in England, but this is, of course, a very costly piece of apparatus and was specially constructed under Lord Kelvin's supervision. The measurement has been made in Germany by passing the alternating current to be measured through a sheet of platinum until it became incandescent. The current through the filament of an incandescent lamp is varied until the filament when seen against the incandescent platinum surface disappears. This lamp current then is held constant while a measured direct current is passed through

the platinum sheet until the lamp filament again disappears. The known direct current and the alternating current are then taken to be equal. But methods such as the above, involving, as they do, elaborate apparatus and direct currents of like magnitude with the alternating currents with which to obtain the constants of the apparatus, are not likely to be used outside of laboratories having a governmental equipment.

By the development of a new method an apparatus has now been designed, known as the Mercury Ammeter, which at relatively slight expense will measure alternating currents with precision of any large magnitude. Barring the extra cost of construction the massive copper terminals needed for conveying heavy alternating currents into the instrument, the expense of construction is approximately the same whether the current to be measured is 1000 or 50,000 amperes. The principles upon which the Mercury Ammeter is based were given in a paper by the writer entitled, "Some Newly Observed Manifestations of Forces in the Interior of an Electric Conductor," Physical Review, June, 1907. At that time a rude instrument was shown which would roughly measure about 600 amperes. Since then experiments have been conducted and instruments constructed with the object of bringing the apparatus and method into a practical form. Success has been secured, and there is shown in Fig. 11 a mercury ammeter suitable for measuring 2000 ammeters alternating current.

The figure is a cut from a cross-sectional drawing that shows the manner in which the instrument is constructed.

The action of the instrument depends upon the essential principle that when a current, direct or alternating, passes through a conductor, there is set up in the conductor an attraction toward its axis of all the imaginary elemental filaments of the conductor. This attraction, when the conductor is a liquid conductor suitably confined in an insulating tubular space, results in a difference of hydrostatic pressure between the axis and the circumference of the conductor. This difference in pressure in a conductor of circular cross-section is numerically equal to the square of the current strength and inversely equal to the cross-sectional area of the conductor. If the conductor is made up of two or more liquid portions in circuit with solid portions, the differences in pressure set up by the passage of the current in the liquid portions may be

added, like electromotive forces, in series and the resultant pressure difference utilized to raise a column of liquid. This raised liquid column may be used to directly measure the value of the current, or the motion of the raising column can be communicated to any style of pointer moving over a scale or dial.

2000 AMPERE
MERCURY AMMETER

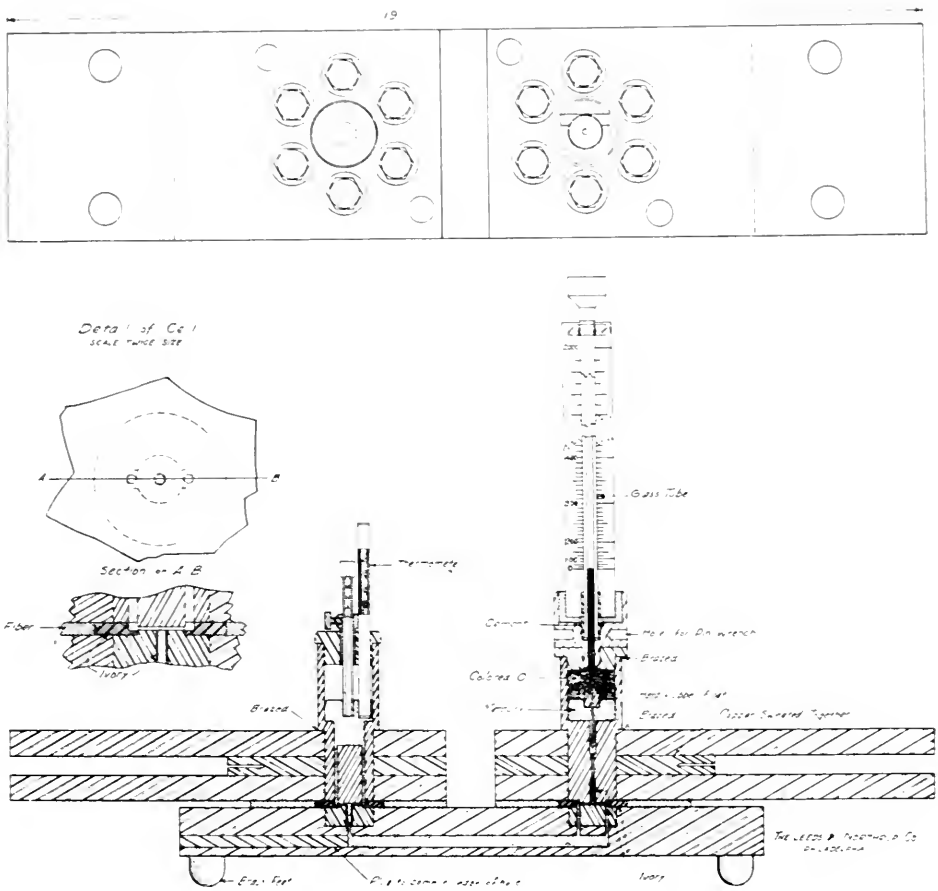


Fig. 11.

The liquid found to be best adapted to use in the construction is mercury. The height to which the mercury column will rise with a given current may be magnified for convenience of observation, but not for accuracy, by causing the pressure to be transferred to a column of colored water. Further description

of the mechanical features of the apparatus is made unnecessary in view of the two illustrations given.

It has only been found necessary to use two mercury pockets or cells and to make these but 1/64th of an inch in their axial dimension. On account of their short length and the proximity of massive copper blocks to rapidly conduct away the heat great current densities may be passed through the cells. In fact 20,000 amperes to the square inch gave a rise in temperature in the cell as measured by a thermo-couple of only 16° C. Mercury has sixty times the resistance of copper, and hence, if this latter metal were to replace the mercury current densities of 1,200,000 amperes per square inch under like conditions could be passed through the short conductor. It may also be shown that keeping the axial length of the cells always the same, the number of watts required to raise a column of water a given height is independent of the number of mercury cells used and the current passing. It is found that approximately 1.4 watts is required for every inch rise of water. Hence, as an ammeter properly constructed can be easily made to dissipate 35 watts, it can be made to give a scale, using water, 25 inches high. When, however, water is used the instrument has a temperature error of $\frac{1}{8}$ per cent. per ten degrees Centigrade, as this represents the increase in the lightness of the water which expends one part in four thousand for every degree Centigrade. For precision work the error may be calculated and allowed for, as the temperature is easily measured. If water is not used the rise in the mercury column may be directly observed with a cathetometer or microscope, in which case the possible precision is very high. The indications are absolutely the same with direct and alternating currents and strictly follow the square law. It is proposed to carefully construct a large mercury ammeter with all its dimensions carefully measured and to employ it in the absolute determination of current. This method would supplement that of the absolute electrodynamometer giving the value of the current as the square root of the area of one cell, the force of gravity times the height to which the mercury raises, times the specific gravity of the mercury and inversely as the square root of the number of cells joined in series.

The mercury ammeter may, if desired, have its constants obtained at one point on the scale by passing a large known storage

battery current through it; the remainder of the scale may then be laid off by calculation and the instrument is then adapted to give precise measurements of large alternating currents. By inserting this instrument in series with the primary of a series transformer of large capacity to measure the primary current and by measuring at the same time the secondary current with the A. C.-D. C. Comparator, or any instrument which has been checked by it, the ratio becomes accurately and experimentally determined. The series transformer with its constants determined in this manner becomes then a truly valuable adjunct in the measurement of large alternating currents. It only remains to determine the phase relations existing between the primary and secondary currents of the transformer to make of it a precision piece of apparatus. The useful lower range of the Mercury Ammeter has not yet been fully determined, but though a 500 ampere instrument is easy to construct, there would be little demand for instruments of similar capacity, as below this precise null methods are available.

Before leaving the subject of the accurate measurement of alternating currents for standardization purposes, mention should be made of the method in which a sensitive electro-dynamometer, with a low resistance astatic moving system, is employed with non-inductive shunts to carry the main current being measured. This method has had a full development at the National Bureau of Standards in the hands of Dr. E. B. Rosa, and is fully described in the Bulletin of the Bureau of Standards, Vol. III, No. 1, p. 43. The constant of the dynamometer is obtained with direct currents under working conditions and the circuits are so arranged that assurance is furnished that the constant is the same for alternating as for direct currents. Substantially the same method of measuring alternating volts, amperes, and watts is embodied in an apparatus originally designed by the late Prof. Henry A. Rowland, of Johns Hopkins University. The dynamometer part of this apparatus is shown in Fig. 12, and known as the Rowland Dynamometer and Shunt Box, and consists essentially of an assemblage of shunts and a wall form of deflection electro-dynamometer with attached telescope and scale to observe deflections. The dynamometer is now made with an astatic moving system which makes it read the same on direct and alternating currents. Its useful range, when used with shunts, is from .001 to 50 amperes. Switches placed upon top of the box

containing the shunts and also non-inductive high resistances serve to quickly give the necessary connections for a large variety of measurements of volts, amperes, and watts. In Rowland's original papers, namely, "The Physical Papers of Henry Augustus Rowland," The Johns Hopkins Press, Baltimore, 1902; "Electrical Measurement by Alternating Currents," by H. A. Rowland, p. 294; and "Electrical Measurements," by H. A. Rowland and T. D. Penniman, p. 314; many methods are given for measuring with this apparatus other electrical quantities, as inductances, capacities, electrolytic resistances, etc. This apparatus and methods of using it are very useful in a laboratory for mak-

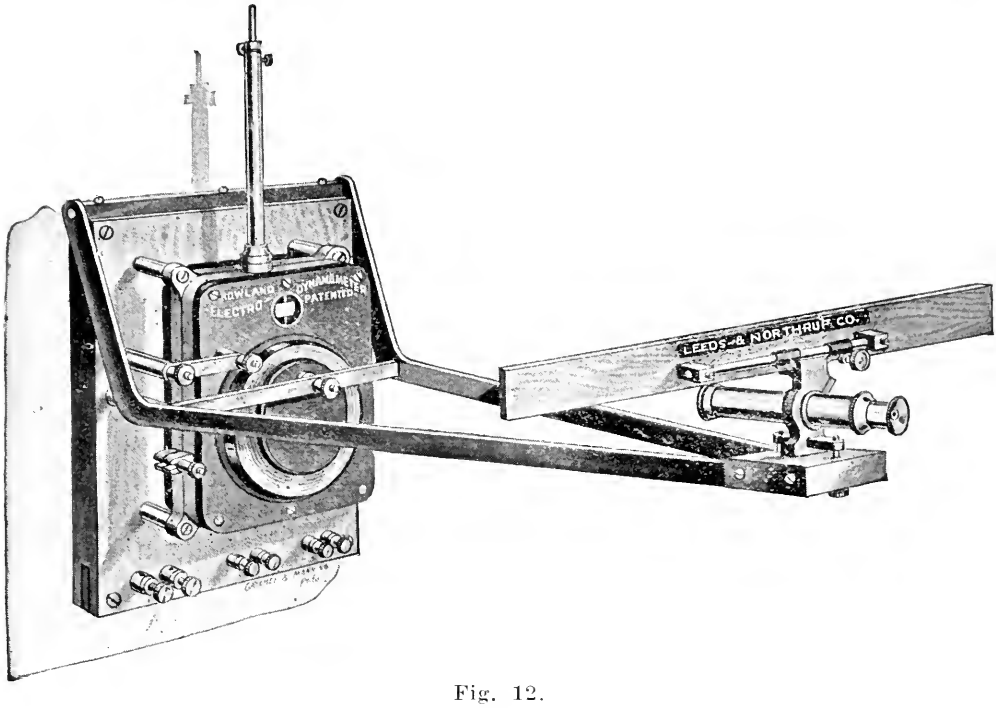


Fig. 12.

ing an extended range and variety of alternating current measurements, but the apparatus and methods are not so well adapted to standardization purposes as the null methods, which are independent of any instrumental constant. By suspending the electrodynamometer system with a very light suspension the instrument may be made sufficiently sensitive to measure with good accuracy the small E.M.F.'s and currents used in telephone practice. In this manner the instrument may be used as a standardization instrument for alternating currents in the range from .0003 to .1 ampere, it being necessary of course to obtain the instrumental constant with direct currents.

STANDARDIZATION WATTMETER.

In the manufacture and sale of alternating current electrical power, the instruments used for measuring this power commercially must be calibrated, and a line of standardization apparatus would be very incomplete, and without the most essential instrument of all, if it did not contain, in addition to apparatus for the precise measurement of volts and amperes, a standard wattmeter capable of registering alternating current power directly and accurately. As has been shown, E.M.F.'s and currents, both direct and alternating, may be measured directly, without introducing any instrumental constants, in terms of the values of resistances and the E.M.F. of the standard cadmium cell. In the direct measurement of alternating current power it is still necessary to bring into the measurements the value of an instrumental constant when the power being measured, as is generally the case, has a power factor less than unity. For this reason, the standard wattmeter, operating upon the electro-dynamometer principle, the only instrument yet devised for the accurate measurement of power of non-unity power factor, requires both for its design and application the most careful consideration. The design and use of the instrument, and the manner of obtaining its constants must be such, that a satisfactory reliance may be placed upon the instrument to give the same indications when used with direct and alternating currents, regardless of wave form and frequency. To give a description of the many features in the design of a standard wattmeter that merit attention would be far beyond the scope of this paper. We shall only show here, Fig. 13, an illustration of a standard wattmeter of 25 to 300 amperes capacity, which has been designed with great care to embody all the features which are needed to make of it a truly standard piece of apparatus which can be relied upon to use in the precise calibration of any form of commercial indicating or integrating wattmeter on alternating current and non-unity power factor circuits.

The most essential features in the construction are the following:

The Siemen's electro-dynamometer principle of construction has been adopted in which the suspended or movable system maintains at the moment of balance a fixed position in the magnetic field, due to the stationary coils. The magnetic forces are bal-

anced by turning a torsion head which twists a suitable suspension sustaining the movable system. The setting of the torsion head is read with a Vernier upon a scale ruled on a hard rubber disc six inches in diameter. The zero position of the moving system is given by a long pointer which has a limited motion over a short scale ruled on ivory and is read from the top of the case by looking through a tubular eye-piece which contains a magnifying lens. The fixed coils of the apparatus are wound to give a field that is strong and nearly uniform in the space in which the sus-

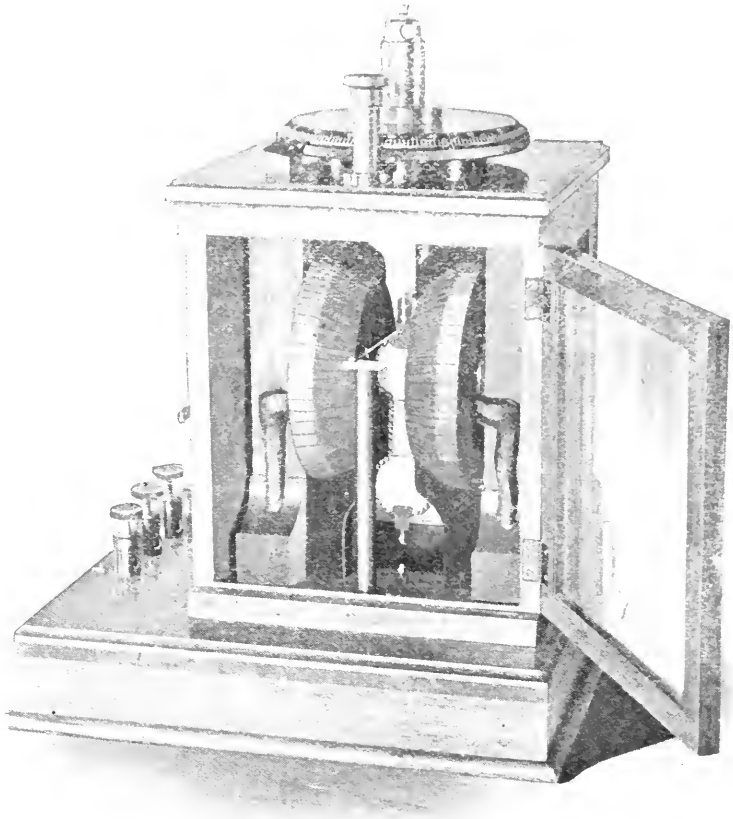


Fig. 13.

pended system swings. The Helmholtz arrangement is used in which the distance between the medial planes of the two coils of the pair is made nearly equal to the mean radius of one of them. The coils themselves are wound with a large number of silk insulated wires in parallel which effectually avoids eddy currents in the coils themselves. By bringing out connections to three binding posts either 10 or 20 turns total may be put in circuit, but

in no case do the alternating currents divide to flow in parallel circuits. A certain foreign designer has been tempted to design a watt-dynamometer, which is widely known, to have many different constants and current ranges in small steps by joining the fixed coils in various parallel combinations. This the writer considers to be very unsafe practice. For, after one set of coils has been in use, they will be at a higher temperature and resistance than the unused coils, and the current will not divide in the same manner as when these coils are first used; besides, alternating currents would be likely to produce currents that would circulate in the closed circuits in a different manner at different times, thus varying in an unknown and unsuspected manner the instrumental constants.

The swinging system of the instrument here illustrated consists of two very light coils which form in respect to the earth's field, and alternating currents in conductors outside of the instrument

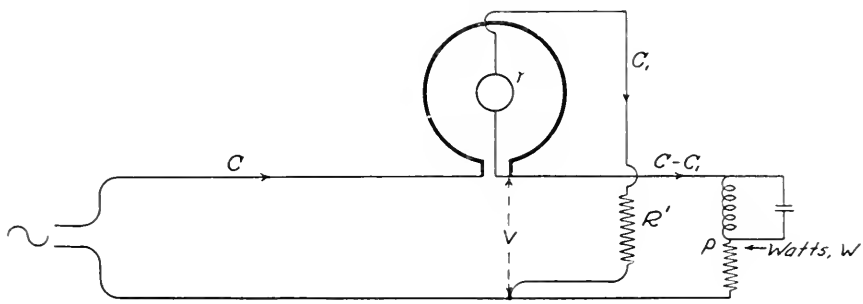


Fig. 14.

case, a perfect astatic combination. This suspended system carries a maximum current of only .04 amperes and may be used for moderate or high voltages with outside non-inductive card resistances of small cost. The system is suspended by a long spiral spring which both sustains its weight and serves by turning the torsion head to oppose the electro-magnetic forces.

The system is made just aperiodic by means of a small mica vane moving in a small hard rubber box filled with a thin oil.

The entire case and supporting frames are of insulating material either mahogany wood or hard rubber. Glass doors make the parts visible and easy to handle and adjust.

In using this instrument to measure power it would be connected into the circuit in the manner shown in Fig. 14.

If it were required to prove beyond any question of doubt that

this form of watt-dynamometer has the same constant for alternating as for direct currents this might be done by measuring with it the watts expended in a perfectly non-inductive load. The watts would then be equal to the square of the current by the non-inductive resistance of the load. The resistance is easily measured and the current may be measured with great precision by the A. C.-D. C. Comparator.

We are thus led to the conclusion that the science of electrical standardization measurements has advanced to a point where all commercial E.M.F.'s and currents, direct and alternating, may be measured with precision directly in terms of resistances and a standard cell, and that alternating current power may be measured accurately but through the medium of an instrumental constant. This constant, however, may be gotten with direct currents measured with a potentiometer, and this may be verified by the alternating current potentiometer or comparator on non-inductive loads.

Any central station possessed of a varied equipment of indicating and integrating commercial instruments and manufacturing electrical power which it sells to the public may, if it so desires, do justice to itself and customers and keep accurately informed regarding its output and losses; for the scientists, instrument makers and the National Government have supplied the direct and inexpensive means.

TIMBER OWNERS ORGANIZE TO FIGHT FIRE.

One of the most important economic movements of the day about which the general public has yet learned little is the concerted action of owners of timber in different parts of the country in organizing associations to protect their holdings from fire. In the Pacific Northwest, the Washington Forest Fire Association has just elected officers at Seattle and begun work for the year with 3,000,000 acres under its care. The plans include a system of patrol by rangers resembling the work done by the United States Forest Service in guarding against and extinguishing fires.

Organizations of similar kind and for a like purpose are at work in Oregon and Idaho. In the latter State, a portion of the expense is borne by taxation and paid from the State Treasury. A Western railroad company, which holds large tracts of timber, has taken steps to guard its property from fire, and during the short time that its plans have been in operation it has met with most encouraging success.

Similar work is being done on the other side of the continent. Forest owners in Maine have gone to work in the same systematic way to control the forests' great enemy, fire. Like organizations are found in other parts of the country, showing how fully it is now realized that protection against fire is of the greatest importance.

(Read at the stated meeting Thursday, January 2d, 1908.)

Cement—Its Use and Abuse.

By Robert W. Lesley, Associate Am. Soc. C. E.

In a recent Government publication, Mr. Gifford Pinchot, Chief of the Forestry Bureau of the Agricultural Department, makes the following statement:

> "In twenty years we may be in the midst of a lumber famine. We have enough standing and matured timber to last that long. With the timber that is growing the famine may be put off five years. One-fifth of the standing timber is embraced in forest reserves. The rest of it belongs to private ownership. We must be economical in the use of lumber."

This fact is corroborated in other Government publications, in speeches by Government officials and in the publications in trade papers representing the lumber industry, the period of time now being reduced to fourteen years. The question, therefore, in view of the destruction of the lumber of our country, is, what material shall be substituted for it? In a new country, with primeval forests, it was but natural that the pioneer and those who followed him in the transformation of clearings into farm lands and cities, should use the resources at hand, and lumber was the first material employed in the construction of our homes, the making of our sidewalks, the building of our highways and railroad bridges and the laying of our first sewers and water mains. As time progressed and wealth and civilization grew, materials of a more fireproof and permanent character came into use, but nevertheless the great consumption of timber kept on until the state of affairs above described has come about.

Steel, stone and brick have all been used in the developing stage of our country as substitutes for lumber, all having their advantages and all representing varying elements of cost. Within the past ten years the development of our natural resources has included the utilization of enormous deposits of land available for

cement-making, which, together with the wonderful mechanical inventions of American cement manufacturers and experts in the production of the cheapest and best Portland cement in the world, has brought about the introduction and establishment of a new, permanent and economical building material, namely, Portland cement concrete.

In considering this new material, whose name indicates its quality—CONCRETE—we must analyze what it is and of what it is composed: (1) Cement, which is the strong binding material; (2) Sand, which is the first aggregate and with which the strong binding material (cement) is primarily mixed; (3) Water, the element that causes the hydrating action of the cement upon the sand; (4) Stone, the large aggregate which is bound together by the material formed of the cement, sand and water. Thus far the actual physical elements constituting this new material, concrete, are closely defined, but there is one element of a human character that goes into the making of this new building material and which is the prime element in its successful manufacture. That element is CARE, CARE, CARE.

It would seem that in the consideration of concrete as an element of construction, it has possibly had too much treatment from the extremely scientific and engineering standpoint, and the writer desires to consider it rather from a new standpoint, namely, that of a manufactured material. In the specifications for the steel that enters into the construction of a building or bridge, every element of chemical and mechanical test is prescribed by the engineer or architect. The steel beam, girder or column is made under the most rigid supervision of chemical and scientific experts in shops or works of the most approved character, and is finally, as the completed and finely finished, fully inspected and scientifically determined, building material, delivered upon the work. This beam, girder or column is a finished building material.

In the matter of concrete the cement has been carefully manufactured in a reputable, well constructed and well officered plant. It has met the chemical and scientific tests of the manufacturer, the inspector and engineer. It is brought upon the work as a finished product so far as its bonding qualities and permanent elements as a cement are concerned. At this point, the writer contends, a manufacturing process begins, and a manufacturing process on the success of which the entire construction of the

building, bridge or other edifice depends. To this cement, so scientifically manufactured and determined is added a sand, the requirements of which may have been covered in a couple of lines hastily thrown together in the specifications, and which, in nine cases out of ten, has had no other test than the mere rubbing of it between the palms of two hands to determine whether or not it shows clay or other coloring substances.

The stone, similarly delivered upon the job, has had no serious inspection other than possibly to know the percentage passing through a two-inch ring. The water, which may contain all sorts of deleterious substances, is seldom, if ever, analyzed, and with these three materials, the qualities of which, in nine cases out of ten, have never been determined chemically or physically, the preparation for the manufacture on the job of the finished beam, girder or column of this new material—concrete—is begun.

When it is considered that the proportion of the cement is 1, of sand 3, of broken stone 6, and the whole to be made plastic and of just the right consistency with water, it can be readily understood that at this point of the manufacturing process there is a possible chance for error in some of the ingredients other than the cement, which is the only one fully equipped at the start for its work by reason of its scientific and careful manufacture, and careful and accurate tests.

When the proposition is stated that the making of concrete is a manufacturing process on the work, every architect and engineer can readily appreciate the importance of knowing the character of all the ingredients entering into his manufactured article, and the writer's purpose in raising this point is to secure the same examination for sand, stone and water as is secured for the cement prior to use in the new manufacturing process.

When the ingredients, properly selected and tested as they would be in any well regulated manufacturing establishment, are brought together there then should come on the part of contractor and engineer the same careful attention, vigilance and thought that govern any other large manufacturing enterprise, and in the making of the beams, girders and columns and other details of a building of concrete, there should be exercised the same care, the same watchfulness and the same everlasting attention to details as is exercised in the manufacturing establishment producing the steel beam, girder or column for a similar building under simi-

lar conditions. The best illustration of the point made above is shown in the little steel beam that I have here and in the jars of the various ingredients entering into the little cement beam also shown. In the one case, all the materials entering into the steel beam have been used and the beam itself finished before it is brought upon the work, while in the other case the materials in these little jars are all separated and the actual manufacture of the concrete beam takes place upon the work itself.

Now, bearing this thought in mind, the causes of failures of concrete become somewhat clearer; they generally go to faults in construction—what I call the "manufacture" of the building. There has never been known, so far as my information goes, the failure of a complete concrete building, though the records are full of cases where such buildings have been loaded beyond the calculated strains, and where in fire they have stood exposure that would have been fatal to buildings of other materials. The failures are always in construction; they always occur through some fault in structural design or in the use of poor sand, poor stone, poor water, poor workmanship, and never in the cement itself. An examination of the reports upon the concrete failures for a single year—some five or six in number—will show conclusively that they occurred only in course of construction, in every case being explainable from one of the causes above mentioned, and illustrating as clearly as can be illustrated to the engineer and architect the point that the writer makes, namely, that the construction of concrete buildings is a manufacturing operation and requires the same care, skill and diligence as the running of any large manufacturing plant.

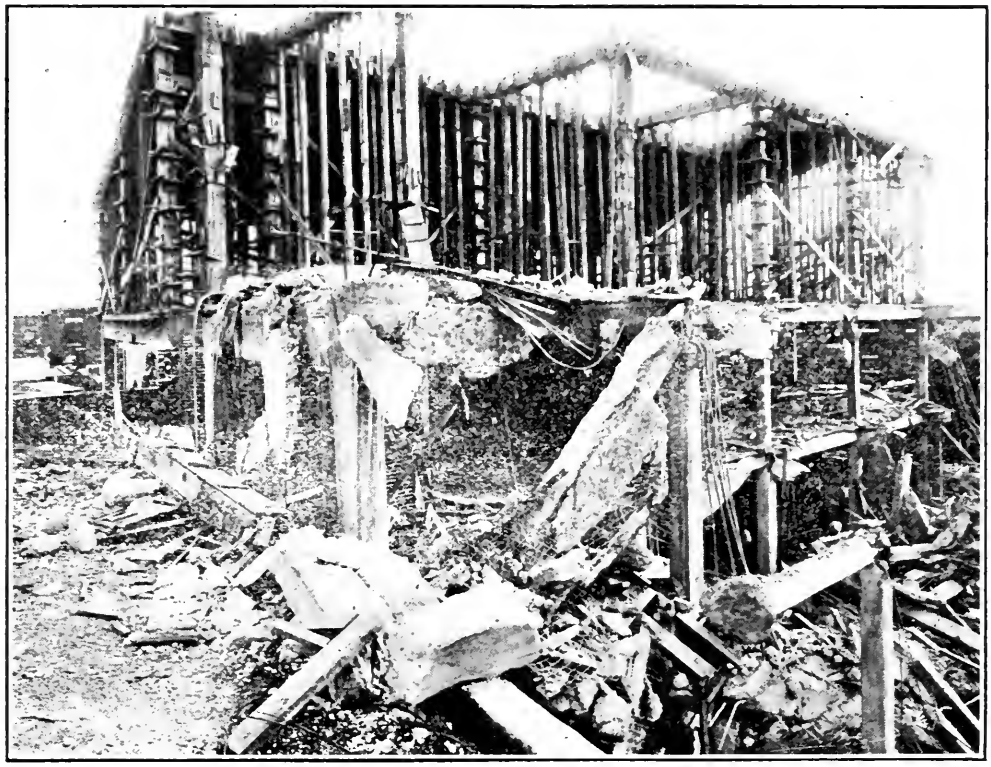
As illustrating this proposition very clearly, the photograph herewith shown of the failure of the Bridgeman Building, in Philadelphia, sets forth exactly the reasons of a concrete failure. In this case it was alleged that the work was carelessly done, the supports were removed too soon and many other errors committed.

One remedy, and one which is likely to come to prevent some of these mistakes, will be the manufacture of cement lumber, or beams and other forms of building construction in the shape of units, in yards or factories away from the work, and the delivery of this cement lumber upon the job, precisely as lumber is now delivered. The development of the Cerutti, Siegwart, Perrot and

other unit form systems of cement lumber is likely to be one of the great features in the growth of concrete construction.

In considering, therefore, this new building material, the writer desires to divide his subject into several heads and to deal with concrete, (1) as a structural material, (2) as an architectural material, and (3) as a decorative material.

As a structural material, concrete in its successes is too well known to need much description at the writer's hands. Building



Philadelphia building collapses. Showing weak character of supports, many of which are spliced.

statistics in this country alone disclose the fact that a great many buildings over eighty-five feet in height and from eight to sixteen stories, have been erected within the short period in which concrete has been used for this purpose and that there are numbers projected, under way or finished in all parts of the United States of the height mentioned. As to the use of concrete in reservoirs, dams, bridges, culverts, tunnels, sub-ways and all other forms of engineering construction, the scientific and engineering papers are full of accounts of such work. It is therefore of the abuses of concrete as a structural material that the writer desires to speak.

Having assumed that as a manufactured material concrete in

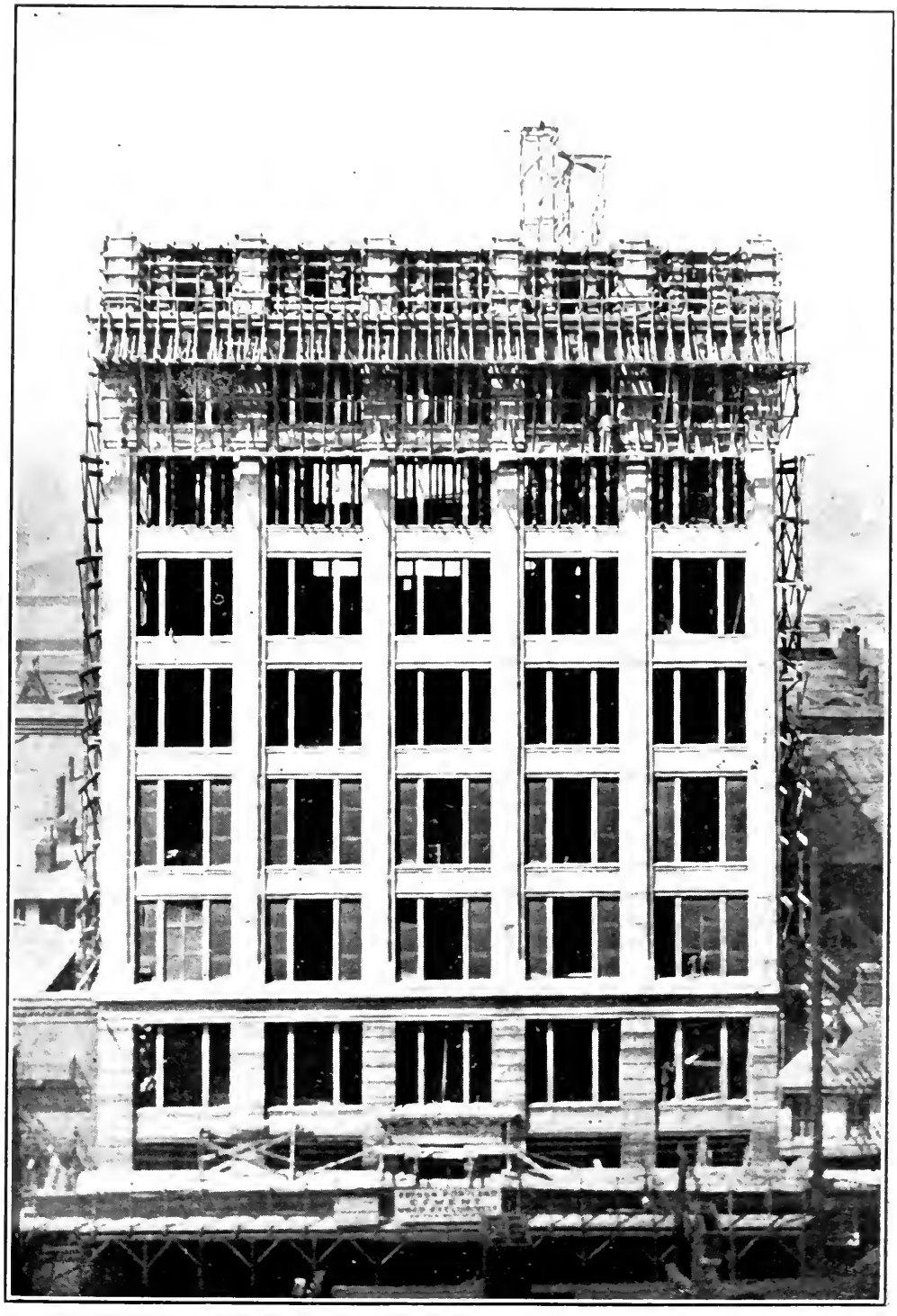
its various forms has been made of proper ingredients and with proper care, the next question comes as to the proper designing of concrete buildings. The designing, so far as the writer is aware, has rarely, if ever, been the cause of serious criticism, but it is in the carrying out of the designing that errors frequently occur. Experience has shown where columns have been improperly placed in course of construction, where beams have not been properly anchored, where reinforcing members have been put in upside down, where expanded metal has been laid with the mesh running the wrong way, and many other cases involving similar errors have been brought out in investigations of concrete construction. The results of such work are shown in the photograph of the Bridgeman Building referred to above.

As some of the concrete failures have been due to the premature removal of the timbering, there have been made a number of suggestions to obviate this, whereby, during the construction of the building, the load would be carried upon especially designed columns, and the final load would be carried by the cement used in the types of columns referred to. Thus there has been made the suggestion of a column made of sheet-iron cylinders which are filled with concrete, the cylinders carrying the load during construction and the hardened cement carrying the live load of the building when in use. Lattice columns designed by Professor Burr and used in the McGraw Building, in New York, furnishes another type contributing to the same result. Mr. Ross F. Tucker, of New York, uses for his columns large cement cylinders, two inches thick, which are in turn filled with concrete and which carry the construction load. This also forms an admirable fireproofing protection to the interior concrete and reinforcement.

All these suggestions and improvements are likely to add much to the safety of concrete work during construction, and would obviate many of the dangers which are improperly imputed to concrete.

Another suggestion made is, that in order to prevent the removal of the forms at too early a date, the contractor should have sufficient lumber to permit of the locking of these forms for a fixed term of days or weeks, to be determined by an examination of similar concrete laid under similar circumstances under the City Building Inspector's supervision on the job itself, and that the unlocking of the forms should only be done by him or his subordinates at a time when he is satisfied that the concrete has

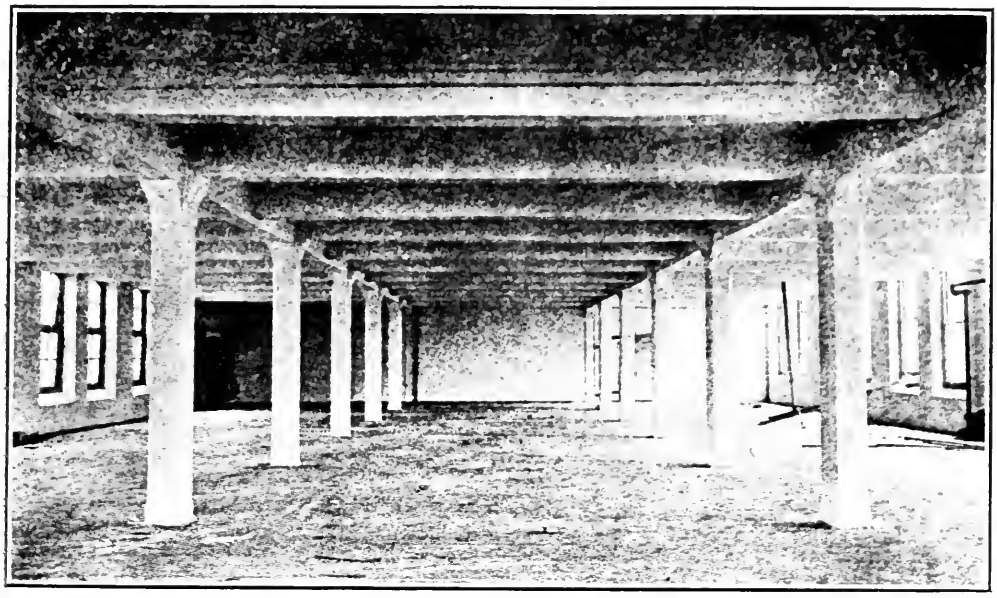
actually hardened. As illustrating the construction of concrete buildings under the most favorable circumstances there are shown the following:



A substantial concrete building, designed by Ballinger & Perrot architects and engineers, Philadelphia.

The highest concrete building in Philadelphia. Plant of the Ketterlinus Lithographic Manufacturing Company, designed by Ballinger & Perrot, Philadelphia.

In dealing with concrete as an *architectural material*, an entirely new field has been opened up. Originally, designers of concrete houses in this country sought to make concrete tell the tale of stone, and by treating it as stone, made blocks imitating stone with which houses have been constructed in many parts of

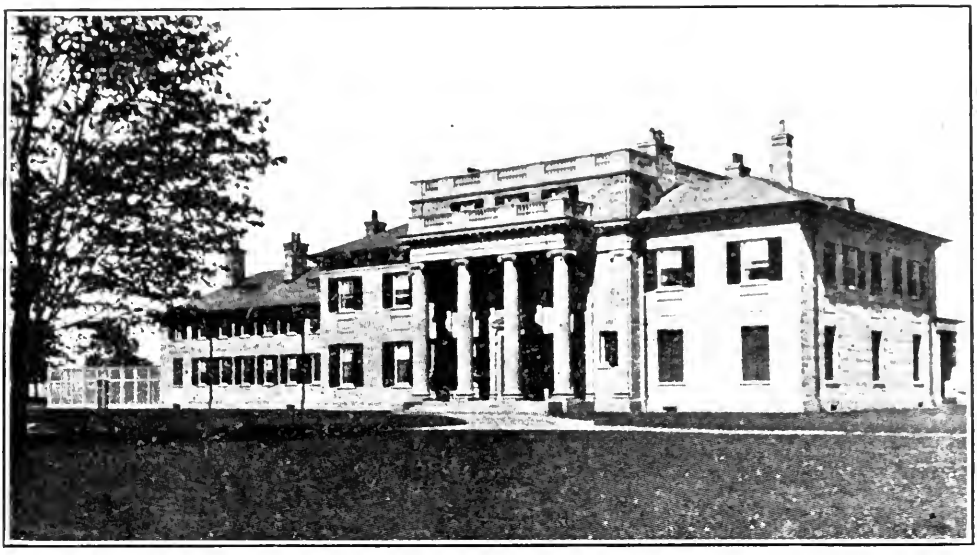


Concrete columns and girders in the plant of the Victor Talking Machine Company, Camden, N.J An excellent illustration of this type of construction. Ballinger & Perrot, architects.

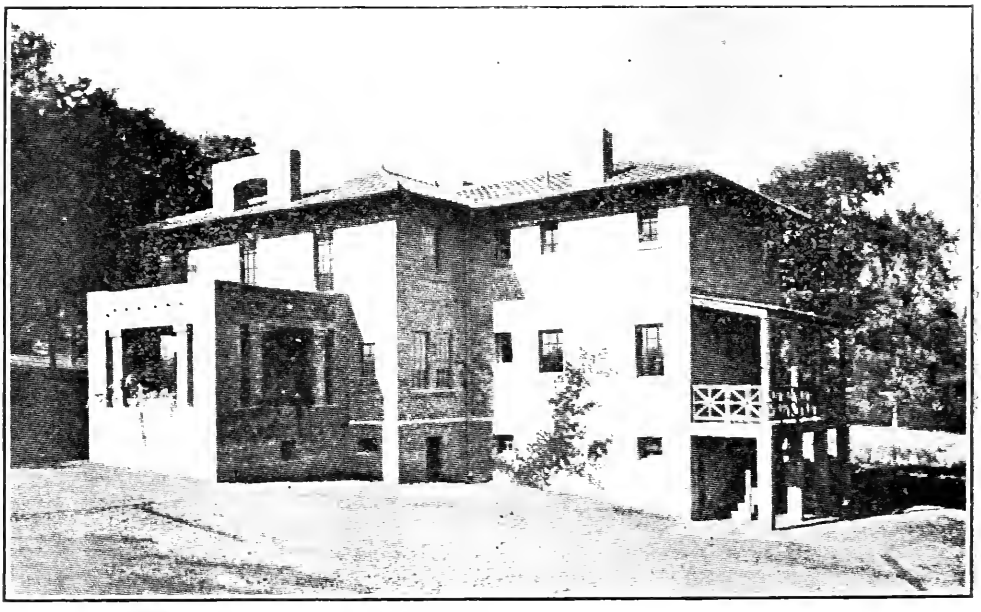
the country. While many of these houses built of blocks are today most excellent in design and construction, there is no question that some of the earlier ones—an example of which block is herewith shown—fail in artistic beauty by seeking to imitate with

Example of block intended to represent rock surface finish.

the plastic material, cement, the rigid material, stone. Cement is capable of much greater beauty when treated as a plastic material. That blocks, however, can make a beautiful house is shown by two illustrations of the Steers Mansion, at Greenwich, Conn. This house demonstrates that block construction, when properly treated, may result in beautiful exteriors, and further proves the



The residence of J. R. Steers at Greenwich, Conn., constructed of hollow concrete blocks, made by the dry process. An example of the approved usage of the concrete block as applied to residence work. Cost $300,000.



Moyer residence. A true concrete house in which aggregate is exposed to give color and pleasing texture.

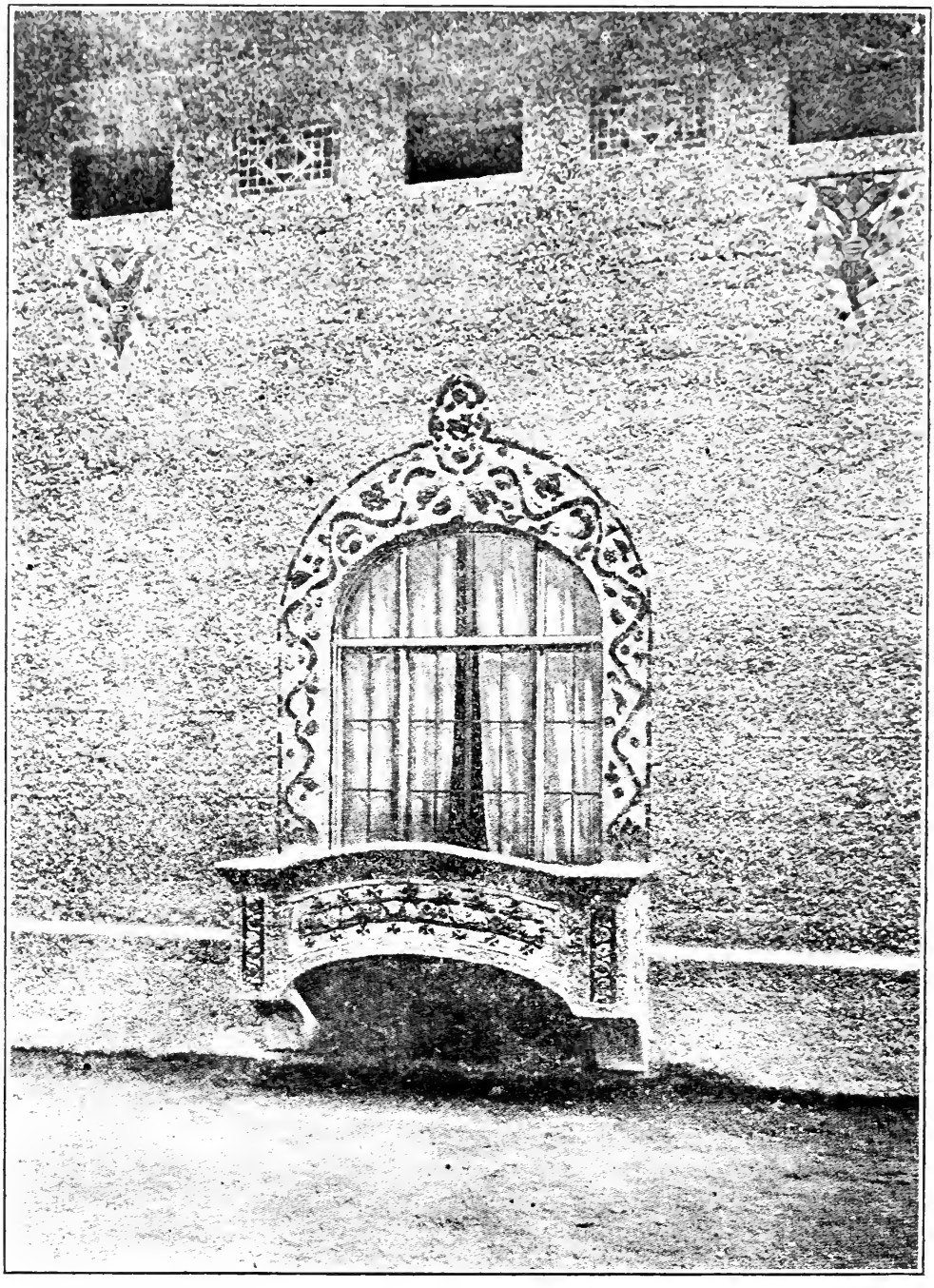
fact that the architectural defects in many of the houses of block construction are not to be charged to the blocks, but are attributable to the manner in which cement blocks have been designed or used.

It is, however, in the field of monolithic construction that concrete is doing its best work. The prominent architects, Carrere & Hastings, demonstrated the beauties of this form of construction when they erected for Mr. Flagler that beautiful group of hotel buildings at St. Augustine, Florida, and emphasized in this form of construction the antiquity and the Spanish atmosphere of that oldest American city. The adaptation of concrete to these beautiful forms of construction, its decorative features when used in combination with tiles, speak volumes for its decorative possibilities. This is also shown in the houses in Southern California, patterned after the old missions and kindred Spanish designs, red hand-made tiles furnishing the color. In the East a beautiful treatment of concrete is shown in the Moyer house, where the solid structural elements of the material are displayed, together with its decorative possibilities when encrusted with tiles.

In the artistic treatment of concrete, our architects have already learned much and are developing to-day in this great country of ours forms of concrete architecture that will be surpassed in no other country. With this material there will develop here a school of architecture, typically American, embodying within itself the beauty of the antique as well as every modern element that this day requires. The discussion of concrete at the recent meeting of the American Institute of Architects, at Chicago, shows the growing interest of the American architect on this subject and his faith in the future development of concrete construction.

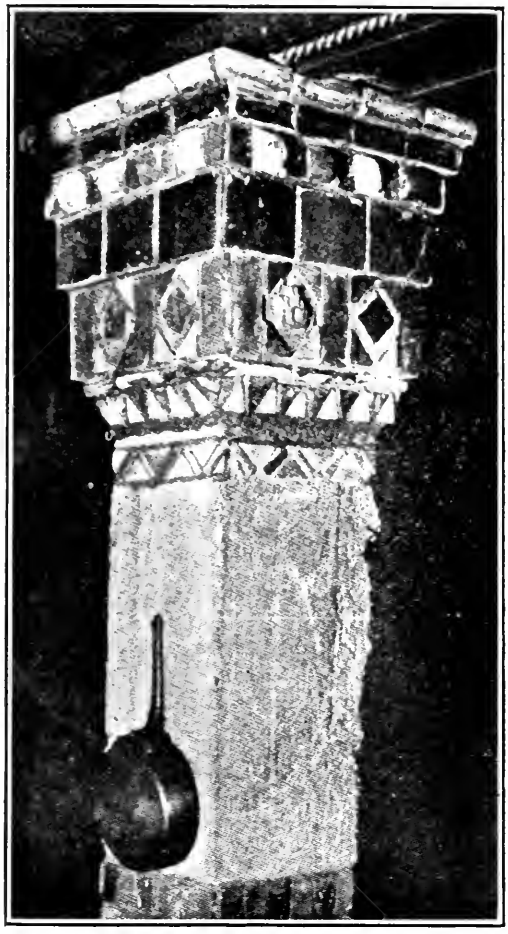
So far as the use and abuse of concrete in *decoration* and treatment of surfaces are concerned, much might be written. Already reference has been made to the various methods of applying it in architectural designs and this leads naturally to the best possible treatment of the surface of concrete to secure satisfactory results. Possibly the Moyer House, which has a peculiar surface, affords one of the best illustrations of the pleasing effect to be obtained upon a concrete surface. A short description of how this was accomplished is as follows, written by Mr. Moyer himself:

"The aggregates used in the house described are composed of

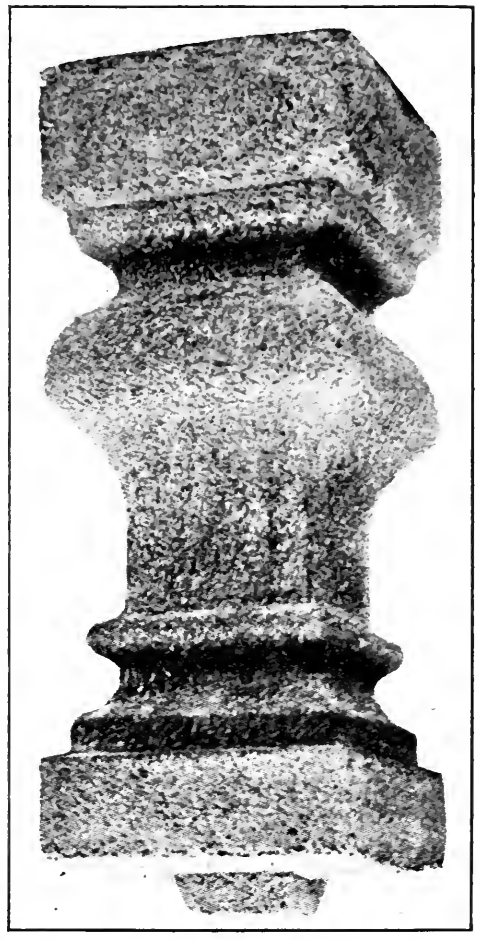


Detail of Moyer house, showing application of colored clay tile on mosaic as window border with wall oraments above. Also colored mosaics and tile.

1 part Vulcanite Portland cement, 3 parts limestone and white marble screenings about the size of sand, 5 parts of three-quarter-inch trap rock, 1 part rock and 1 part of one-inch white marble chips. When the boards were taken down the surface had the appearance of ordinary dead mouse-colored concrete, but as soon



Mercer tiles in Concrete. Racquet Club, Philadelphia. Column of Byzantine pattern in original unplastered concrete supporting heavy ceiling. The capital is ornamented with colored tiles, glazed and unglazed, flat and in relief. Colors, yellow, green, blue, gray, red, white and buff. Tiles were applied after removal of forms and the exposed undecorated portions of column left just as they appeared after removal of forms so as to develop contrast with tiles, both in color and texture.



Concrete bridge baluster treated by Quimby process. One part cement, three parts unscreened dark stone grit.

as scrubbed and washed with a hose, all the particles of trap rock, white marble chips, bonded together by light-colored mortar, were exposed, giving a surface which was slightly roughened, and a color effect and texture which are beautiful. Photographs do

not do justice to the color of this wall; it is bright and full of life. It is a true artistic and picturesque monolithic concrete house."

The work of Mr. Quimby, described in "Cement Age" of November, 1906, is also most interesting and instructive. Some of his surfaces shown herewith suggest other methods of treating concrete surfaces.

Mr. Henry C. Mercer has also developed in the Racquet Club, Philadelphia, practically a new school of concrete decoration and artistic treatment. Some of the accompanying illustrations show what can be done with cement and tiles by treating concrete frankly, even though these views indicate imperfectly the importance of this work, for you must picture to yourself the brilliant color of the tiles and the contrast between the dull gray of the cement and the mass of decorative color embedded within it.

So far as the abuses of concrete surfaces are concerned, the cast "cut-stone" blocks above referred to are fair illustrations, and it may be stated as a broad proposition that concrete is concrete with its own tale to tell and has a surface of its own to speak for itself, and wherever this surface is changed into some other material or some other surface, imitating some other material, it is very likely to be wrong from a decorative and artistic standpoint. The exception is where it is hammer dressed or cut by tools, as in the case of stone. This is an important distinction I wish to emphasize. Given two blocks of stone, one of concrete or artificial stone, and the other natural stone, it is manifestly possible to have them equally meritorious by cutting both or treating them in the same fashion, for in surface decoration we have by this method removed concrete from the domain of a plastic material. But when we attempt to reproduce this cut surface by casting it in a mold, then we do violence to a plastic process or art which results in monotonous repetition. Of course, this does not apply to columns, capitals or cornices. I am speaking of broad surfaces in monolith or made up of many units.

In conclusion, the writer can only add that from a long experience in the cement manufacturing industry, dating back to its pioneer days, in the early seventies, he has seen the growth of the industry himself and the growth of all the uses of this wonderful material, cement, and looking back over the long period covered by his connection with the industry, he has seen the great growth of concrete construction in all its forms to a degree beyond the

Mercer tiles in Racquet Club, Philadelphia. View of detail in Gothic fireplace adapted from original of the 14th century in castle at Trebbio, district of Sicci, near Florence. Frieze, banding and columns composed of glazed and unglazed tiles applied after the construction of the fireplace. The flatness of the large concrete area or face is broken by widely placed relief tiles silhoutte.

expectations of the most sanguine. He has seen concrete gradually take the place of other materials because of its great strength, its fireproof qualities and its economical elements. He has seen it develop from the architectural and engineering standpoint; he has seen it grow in decorative and artistic possibilities, and it is his conclusion that concrete honestly, carefully and properly made, in buildings properly constructed and designed, will, with the present knowledge of the architectural capabilities and the artistic qualities of concrete, ultimately supersede for most uses the present materials of construction.

AMERICA USES MANY BARRELS.

Upwards of 150,000,000 barrels and circular packages are manufactured in the United States annually. Few people, except those whose business it is to know, realize the extensiveness of the cooperage industry in this country.

The heaviest demand comes from the cement business. The flour business ranks next, closely followed by sugar. Containers for fence staples, bolts, nuts, nails, and packages for roasted coffee, spices, crockery, fruits, vegetables, follow in the order named, while glass manufacturers, baking powder companies, liquor distillers, and candy, tobacco, and cheese packers are big users of barrels. The demand for barrels for molasses, oil, lard, and pork is also enormous, while dry paint, glue, snuff, oatmeal, screws, castings, and general hardwood articles annually increase the demand on the cooperage supply.

While the amount of expenditure for barrels can be quite closely estimated for a given year, it is not possible to say how many barrels are in actual use. The life of a barrel is put down at one year by the trade, but this is far from true. A majority of barrels are used many times. They begin as sugar or flour barrels, and are then sold to the farmer for shipping his produce to the market. It may be that they are returned to him several times, carrying potatoes to the market on the first trip, and tobacco or lettuce on the next, each cargo being lighter in weight than the previous one, owing to the weakened condition of the barrel. Finally the barrel may serve out its work as a refuse receptacle, and in the end can be used for fuel. Thus, it may be said, that a barrel fills as useful a career as almost any other manufactured article, and its life is much longer than a season.

The demand for barrels is steadily growing because modern machinery has made it possible to make them for the trade cheaper than almost any other form of durable package. That it is the most convenient form of package has long been acknowledged. The timber used in tight barrels has to be selected with care, as it must not only be water-tight, but barrels for the oil, whiskey, and paint trades in addition must be capable of resisting high internal pressure. The lumber used for this work must be carefully selected, that cured by slow air drying under shelter being the most satisfactory.

Mechanical and Engineering Section.

"A Wheel In the Middle of a Wheel."

Waterway Legislation.*

By Lewis M. Haupt, C.E., A.B., Sc.D.

In the May number of the *Journal,* attention was called to the comparatively undeveloped condition of the waterways of the United States and the efforts which were pending to so modify the National policy that they might be improved more systematically.

With no uncertain sound the President has laid stress upon the necessity for regulation and relief of the transportation system of the country, stating that "The rivers of no other civilized country are so poorly developed, so little used, or play so small a part in the industrial life of the nation as those of the United States." He has appointed the distinguished commission, which presented its preliminary report February 26th, 1908, to the "First Session, Sixtieth Congress (Senate Document No. 325)," which report was submitted with a view of urging early action by Congress looking to immediate relief. A bill was introduced in the House of Representatives to perpetuate this Inland Waterways Commission, by its Chairman, Hon. Theodore E. Burton, and appropriating $20,000 for its expenses in pursuing investigations, which bill passed the House with only two negative votes, but failed of approval in the Senate. In commenting on this defeat of so necessary a measure the "Engineering News" of June 4th, says editorially: "Is it possible that the Senators prefer the present lack of system, with its barter and sale, its log-rolling and its many opportunities for political manipulation?"

The question is left to be answered by the people. It would seem, however, that notwithstanding the great popular movement which has been held during the present session and the all-but

---

* Read by title.

unanimous demand for $50,000,000 annual appropriations for waterways, the attitude of Congress is uncertain and action is deferred on the ground that the "public sentiment" will not justify such expenditures.

This is the more remarkable in view of the action taken by the great and enthusiastic Waterways Congress held in Washington, December 4-6, 1907, which was presided over by the Honorable Jos. E. Ransdell, M.C., of Louisiana, when the following resolutions were reported, "representing the sentiments of thirty-seven State and Territorial representatives:"

Be it resolved; First, That we earnestly urge the adoption by the Federal Government of a wise, liberal and comprehensive waterway policy that will provide for the proper improvement, within the next ten years, of the rivers, waterways and harbors of our country, the improvement of which *is justified** by present and prospective benefits to commerce.

Second, That without presuming to prescribe the engineering or the financial details of this great undertaking, this Congress strongly urges upon the Congress of the United States the importance of the *immediate adoption of a comprehensive plan of waterway improvement,** of the carrying on of the work by an adequate number of engineers, and of such liberal appropriation annually as will insure the early completion of such objects as may be undertaken.

Third, That we cordially endorse the action of President Roosevelt in appointing a special Inland Waterways Commission, being confident that the report will prove a source of accurate and valuable information to the American people. We further recommend that Congress enact such laws as will make the Inland Waterways Commission permanent, and will provide it with necessary authority for its investigations and recommendations.

Fourth. That this Congress cordially thanks President Roosevelt for the support he has given to its purposes, by his speeches, and by his treatment of the subject in his recent message to Congress.

Fifth. That we ask Congress to view the river, waterway and harbor appropriations not as the appropriation of money for current expenses of government, but as an investment in perma-

*The italics are the writer's.

nent improvements, bound to pay increasing dividends from year to year. Viewing these appropriations in this light Congress is fully warranted in authorizing an annual expenditure, beginning at the present session, of not less than one-tenth of the amount of money required for all the various rivers, waterway and harbor improvements already planned and approved by the engineers in charge or hereafter planned and approved, in order that the work may be carried to speedy completion, such appropriation to be not less than $50,000,000 annually, and Congress is further warranted in authorizing the expenditure of the money as needed, and in providing for the same, if in excess of funds available, by a bond issue similar in character to that for the building of the Panama Canal, whereby part of the cost of these vast improvements will be spread over a succession of years, and borne by all who share the benefits. Signed, J. Hampton Moore, Chairman Committee on Resolutions.

Nearly two thousand delegates were present, representing all classes of interests and industries from all parts of the Union, and the feeling was very pronounced as to the *necessity for immediate action*, yet within six months of that date Congress has adjourned without passing either a river and harbor appropriation bill or even providing for the support of the Commission to prepare a definite policy for these vitalizing improvements.

Is the partisan, political aspect more potent than the urgent request of the business interests of the nation at this critical juncture?

Many local organizations have taken similar action, but suffice it to refer to the action of the National Business League of America, which at its meeting held May 25th, also passed a series of resolutions covering the larger scope of our public utilities for the consideration of which the first conference of the Governors of the several States was held at the White House from the 13th to the 15th of May. They read: "*Resolved*, That * * * (we) recommend the forwarding of the following economic public measure, of grave importance, as involving the future welfare of the American people.

First. Systematic conservation and reproduction of the forest reserves, for the perpetuity of our water courses, water powers, agriculture, industries and commerce, and for the prevention of disastrous floods and erosion of the soil.

Second. Reclamation of arid lands by irrigation and of swamps and overflowed lands by drainage.

Third. Equitable distribution of arable lands in small farms, to home builders only.

Fourth. Husbanding of oil deposits; of coal, copper, iron, and other products of the mine.

Fifth. Construction of better common highways from the farms to the mills and markets of the country, and creation of a comprehensive system of navigable inland waterways by the Commonwealths and the Nation.

Sixth. Cöoperation of art with nature to enhance the beauty of the landscapes, the nooks and by-ways and to create more healthful conditions for the people.

Seventh. Enactment of national statutes to adequately cover the measures herein recommended and repeal of all laws in conflict therewith."

This last recommendation, being paramount to any progress, should be considered first, as it involves the entire question of authority, jurisdiction, means and method. As the determination of these details have so long hampered the normal progress of our country it is of prime importance that a few fundamental principles be established in the hope that they may point the means to the end.

It is indubitably desirable that the organized, constituent bodies of the States and Nation should devote as liberal a percentage of their revenues to the creation and conservation of public utilities, to be leased and operated if desired under corporate management for a term of years.

It is unwise to attempt to centralize these great and multifarious operations under one extrinsic authority, requiring approval of plans, details and organization, or of appropriations from the national treasury, in a country reaching more than half way around the globe.

Experience has demonstrated the futility of such attempts by the failure of many urgent projects because of the impracticability of meeting the demands from all sections, for ample appropriations or by the opposition of hostile vested interests, fearing competition. Thus, a State or Nation undertaking to direct all industries would be overwhelmed in a short time and its machinery would be paralyzed.

There must be a careful segregation of the duties and powers of government, which are supposed to rest with the people from whom they are derived, so that they may be intelligently and promptly applied to the needs and resources of any locality as they may exist at the time.

This spirit of Government has been concisely stated by John C. Calhoun in his address to the Memphis Conference many years ago, when the nation was young. He said: "It was the Genius of our Government, and what was to him its beautiful feature, that *what individual enterprise could effect alone, was to be left to individual enterprise; what a State and individuals could achieve together, was left to the joint action of States and individuals; but what neither of these, separately or conjoined were able to accomplish, that and that only, was the province of the Federal Government.*"*

The safety of this policy which was pursued up to the time of the Civil War, will be seen by reference to the legislation of those ante-bellum days when there were no dominant industrial interests to check development. They present a striking contrast with the present failure to pass any bills looking to the relief of commerce or the restoration of our merchant marine, yet about $400,000,000 are applied at the session just closed to the devastating art of war and its sequence, pensions, which latter item has been increased about $20,000,000 at the recent session.

This failure to provide for waterway improvements or for the continuation of the Commission to consider methods of relief for our domestic commerce, is significant of the helplessness of Congress, where the responsibility is divided, hence the words of Senator Knox will bear repetition in view of the sequel: "When the Government assumed charge of the navigable streams of the interior it entered into a practical contract with the States and communities bordering these streams that their waterways would be improved to their highest capacity. The States were thereby prevented from improving the streams themselves.

"Corporate enterprise was forbidden to undertake the canalization of important stretches and fix the cost of their works and franchises on the traffic. The Federal Government has made its formal and deliberate declaration that it will do this work. That

*The Manufacturers' Record, April 30, 1908.

necessarily involves that it will make the improvements adequate to modern needs and possibilities. To do any less would be a mockery and breach of good faith."

The question immediately arises as to whether the "*assumption*" of jurisdiction over water lying wholly within a State, and without her consent, constitutes a valid contract? It would seem that, regardless of such legislation by some former Congress, many of the States have definitely ignored such a construction of the Constitution, and are expending large sums upon their own internal improvements, in accord with the authority specifically reserved by them when they ratified the Constitution of the United States. Then it was stated, Amendments, Article X:

"The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively or to the people."

The powers thus delegated are stated in Article I, Section 8, where eighteen specific acts are enumeratd, amongst which are "(3) to regulate commerce with foreign nations, and among the several States and with the Indian tribes." The rights of the people are still further guarded by the Ninth Amendment, which states that "The enumeration in the Constitution of certain rights shall not be construed to deny or disparage others retained by the people."

Yet, under what is characterized as the "law of expediency," the functions of a centralized, extrinsic control have been gradually extended over all waterways, improved or otherwise, to such an extent as to have paralyzed local efforts, under the delusion that some day and somehow the Nation may provide the long-desired relief, and the Nation replies: "Not so long as there is not sufficient tonnage to justify an appropriation."

In this connection it is well to note that it was to prevent "rate-cutting" between the several States that the constitution was adopted, but not to construct lines of internal communication under Government control or by Executive authority, and that this idea was so firmly impressed upon the early Presidents that Thos. Jefferson in his Message to Congress of December 2, 1806, recommended that authority be vested in the Government by an amendment providing for the use of the public funds in certain cases—in the building of roads, improvement of rivers and for public education and other improvements; while President Mon-

roe vetoed a bill making appropriations for rivers and canals on the ground of its unconstitutionality. As will be seen later, however, the policy of lending aid to the States and corporations under them extensively prevailed up to about the time of the civil war, when the Government extended its jurisdiction over internal improvements and transportation.

RETARDATION OF NATIONAL RESOURCES.

The proposition to further extend the powers of the Government to divert the revenues to be derived from the water-powers of the States into the National Treasury, is shown by the several bills which were introduced at the last session, of which it is said, "None of them gives the Government the right to make a reasonable charge for the valuable privileges so granted, in spite of the fact that these water-power privileges are equivalent to many thousands of acres of the best coal lands for the production of power."

In this comparison of relative values it should be observed that the use of the water in a mill or factory, merely for the dynamic energy which it gives out, is an indestructible property, which is not impaired in the using, nor is the quantity of the water diminished by its temporary diversion through the flume or penstock of the mill. It flows on forever to the sea and it returns by natural agencies to the place whence it came, that it may bless the nations of the earth. It is now proposed to tax this Divine benefaction, thus adding to the cost of the operation of the power plants and their products and compelling the manufacturer to collect from the people the revenues he must return to the Government for the opportunities he may wish to utilize in his business. Thus an obstacle is to be placed "*in restraint of trade*" by charging for a franchise which is now running to waste and which might be utilized without impairment, for the benefit of humanity and the peaceful employment of labor, or the distribution of power to remote localities.

With the coal fields the case is entirely different. Their energy once consumed, ends in smoke and cannot be returned. Timber, however, has an inherent power of reproduction, and by conservative management may be able to replace itself, if protected from wanton waste and fires. This is now being done

largely by the States and the Government, under its most efficient Chief Forester, while it is notable that efforts to secure the great Appalachian reserve by National legislation, have thus far failed.

The enormous advantages possessed by the great water-powers of the country have not been appreciated as they should have been, because of the large sums invested in coal and timber properties and in the transportation of those products, and a tax on water-powers means a heavy draught on the coal and lumber, but their rapid extinction will ultimately compel the utilization of the ascendant power as a cheap substitute for many of the industrial operations of mill and factory. Probably no one agency will have a more beneficial effect in retarding the destruction of our coal and timber resources than the more general use of water-powers for long distance transmission, whether by electric or compressed air conduits. To this end *liberal legislation should be encouraged, and no unnecessary restrictions should be placed upon the utilization of these powers, either by the National Government or by the States.* Even where dams are built for the purposes of navigation, the power thus generated could be freely given to encourage the establishment of industries, from which the Government or State would derive its returns in other forms of taxation as at present.

THE POLICY OF PUBLIC WORKS.

In a comprehensive review of the policy of the Nation in reference to its waterways, "Shipping Illustrated" of April 4, 1908, remarks that according to the President, "No single agency has been responsible under Congress for making the best use of our rivers, or for exercising forethought in their development. In the absence of a comprehensive plan, the only safe policy was one of repression and procrastination." Yet it may be noted that many Boards and Commissions have been appointed from time to time, and very large sums have been expended in tentative efforts to better the navigable channels with results which he has declared to be inferior to those of any other civilized country—"largely negative." The policy of repression and procrastination continues—and the consistent plans are not formulated but left "to the whims of politics and the vagaries of the steering committees at Washington"—of which Prof. F. J. Stimson, in his analysis of the "*American Constitution*" says: (p. 90.)

"I would now call attention to the fact that the phrase 'Commerce among the several States,' one of the only three phrases in all the powers given to Congress which are not purely political, under the interpretation proposed by President Roosevelt, would alter our Constitution more radically than almost any amendment could do. It will cease to be purely political, but will thrust its hand between every man and his neighbor, between every man and his own property. * * * The States will lose control of most of their business affairs, will *lose the power to tax their own enterprises*, will see their courts shorn of their jurisdiction."

"Hardly any business will be so small, so local, as to be left to the State power to control. We shall all be under the Government of Washington * * * quite as completely and much more hopelessly than the English of the twelfth century were under the power of the royal chief justice of the Norman kings."

And as to the alleged necessity for applying to Congress for the right to make waterway improvements under this clause of the Constitution Prof. Stimson very clearly states:—

"No powers can be delegated by the United States to the States, or still more to the people. It is the other way about. It is the people of the States who delegate powers to the United States. Again * * * to relegate a political power to the States, misstates the principle of the American Constitution. The Nation can relegate nothing to the State. It is the State or the people that delegates powers to the Nation."

So that, falling back on the *lex loci*, which is as old as the Constitution itself, it is found that the right to make improvements in the waterways of the land, of chartering corporations under State authority, for this purpose, of charging tolls thereon or of selling the powers generated thereby, have ever been the inherent property of the States and their citizens, and they have never been relegated to the Nation. Any trespass upon these rights would be in violation of the sovereignty of the States.* Numerous legal opinions might be cited in support of both the law and the policy of such local control and development. The following is pertinent:

The early demand for deeper water in the Ohio River, at all seasons, led to frequent propositions for its improvement, and

*See Shipping Illustrated, 116 Produce Ex., New York, April 4.

many conflicting opinions were advanced as to methods and cost. In these the officials of the Pennsylvania Railroad Company took an active part, and in 1855 a system of canalization by low dams and restraining reservoirs with chutes was proposed, but the interferences from political sources were so great that it was concluded that it were "better to let the Ohio remain forever unimproved than, if improved, to be managed and controlled by partisan agencies." We fully concur in the opinion expressed by the Hon. Jeremiah Black of the Supreme Court, that the improvement should be made and managed by a company, to be formed of citizens under a charter approved by all the States bordering on the Ohio. * * * The general Government can well afford to make a liberal appropriation in consideration of being forever released from the present annual expenditures. The States immediately interested should do something and be entitled to a representation in the direction, and individuals would do the rest. The rates of toll should be restricted to such an extent as to afford no greater revenue than will suffice to keep the work in proper condition, and pay the shareholders moderate dividends.

In further illustration of the well-established policy of Government aid to States and corporations, the following extracts are taken from the able compendium of Hon. B. F. Frovel, of Georgia, relative to the proposed Atlantic and Great Western Canal, across the Piedmont plateau, which is again being urged as a short cut from the Tennessee River to the Georgia Coast.

In this report, submitted January 18, 1873, to the House of Representatives of the Forty-second Congress, Third Session (Mis. Doc., No. 52), he says: "Believing, as I do, that Congress possesses the right to appropriate money for such a national object, *the jurisdiction remaining to the States through which the canal would pass,* I submit it to your consideration. (House Journal 1823-24, pp. 19 and 20)" * * * It appears from the journals of that date that this object did receive consideration, and that these deliberations resulted in the following Acts:

April 30, 1824. Appropriating $30,000 for the survey of canals and roads.

May 26, 1824. Authorizing Indiana to open a canal through *public* lands connecting the Wabash and Miami Rivers.

March 3, 1826. Authorizing a survey of a route for a canal connecting the Atlantic and the Gulf of Mexico.

April 14, 1826. Authorizing Pennsylvania to construct a canal through the public ground near the city of Pittsburgh.

May 13, 1826. Subscribing $100,000 to the Louisville and Portland Canal Co.

May 18, 1826. Subscribing $60,000 to the Dismal Swamp Canal Co.

May 2, 1827. Granting land to Indiana for a canal to unite the Wabash River with Lake Erie.

May 24, 1828. Granting land to Ohio to extend the Miami Canal from Dayton to Lake Erie.

March 2, 1829. Subscribing $75,000 to the stock of the Chesapeake and Delaware Canal Co. and $20,000 additional to the Dismal Swamp Canal Co.

March 2, 1829. Subscribing $135,000 additional to the stock of the Louisville and Portland Canal Co.

April 2, 1830. Granting lands to the State of Ohio to construct canals.

February 12, 1831. Authorizing Alabama to contract for and construct a canal around the Muscle Shoals (on public lands).

May 29, 1830. Granting lands to the State of Indiana for the Wabash and Erie Canal.

May 2, 1831. Authorizing Florida to open a canal through public lands.

July 4, 1832. Providing for a survey of a canal route from St. Andrew's Bay to the Chattahoochee and Pensacola Bay and along the northern coast of the Gulf of Mexico.

March 2, 1833. Granting lands to Illinois for a canal to connect the Illinois River with Lake Michigan.

February 27, 1841. Granting lands to Indiana for the Wabash and Erie Canal.

March 3, 1845. Granting additional lands for the same purpose.

June 30, 1834. Granting lands to Ohio for the Wabash and Erie Canal.

June 18, 1838. Granting lands to Illinois for the Illinois and Rock River Canal.

April 10, 1866. Granting lands to Wisconsin for the breakwater and ship canal.

August 26, 1852. Granting lands to the St. Mary's Ship Canal, Michigan.

March 3, 1865. Granting lands to the Portage Lake and Lake Superior Ship Canal.

July 3, 1866. Additional grants for the same purpose.

July 3, 1866. Granting lands for a canal to connect Lake Superior with Lac La Belle.

"Since then the Des Moines Canal, the Fox River and Green Bay Canal, the canal around Sauk Rapids, the Illinois and Michigan Canal, and other works of similar character have received Federal aid, either directly by appropriations of money or by grants of land from the Treasury. As early as 1809, we find that an appropriation was made for the opening of a canal from Lake Pontchartrain to the Mississippi as a defensive means. These several Acts, extending through every administration from Madison down to the present time, would seem to show that it has always been the policy of the Government to aid and foster these enterprises, as not only necessary and contributing to the National defense, but essential to our commercial prosperity."

The enormous land subsidies made to private corporations to encourage the construction of the overland railways serve to enforce this National policy, under which the rail transportation interest has been so carefully fostered that it has become the greatest in the world, but unfortunately the child has become the father of the man and has so far throttled his benefactor, the waterway, as to have almost destroyed his development, by centralizing the control of his growth and denied him the necessary alimentation from the National crib. To-day the policy seems to be reversed and to require a preliminary contribution from the localities desiring improvement before consent may be obtained in some instances even for the requisite surveys. The astounding result has been that under the old régime about 5000 miles of canals and improved waterways were constructed and in operation at a cost to the Government of less than $15,000,000; while under the new it has expended more than $550,000,000 on its rivers and harbors, while the interior canals and slackwater improvements have decreased in mileage about fifty per cent.

PROPOSED LEGISLATION.

The late congestion of the overland traffic, resulting in serious delays, has called for relief by water, and to this end numerous bills have been presented looking to a complete reorganization of

the system of conducting these works and the placing of their control on a more permanent basis under the National Government, but still subject to frequent changes of personnel and the distribution of an enormous patronage by the Executive Departments, without whose consent first being secured no such works may as a rule be undertaken.

A fair idea of the scope and power to be conferred upon the Executive by the Legislative Department and the manner in which the latter may be subordinate to the former, or the reverse, according to whether the issue may be an approval of plans, or of securing appropriations of sufficient amounts to be effective, may be seen from a brief digest of one of the bills to create a Department of Public Works, to which shall be transferred a number of the Bureaus from other departments, and to empower its Secretary, a Cabinet officer, to make investigations and reports, and "*only in so far as may be authorized by Congress*, to carry out such plans and to construct and maintain the necessary works."

"That the skill and ability acquired by the energies of the Army shall not be lost to the Government, and that their services may be rendered the more valuable in time of war, provision is made whereby the President may detail officers of the Army, as well as employees and officials of other Executive departments, to duty in this one * * * that the officers of the Army shall not only have opportunity for the planning and erection of hydraulic works, but shall also have opportunity for actual work upon those branches of engineering which will most fit them for their duties as military engineers, namely, upon topographic surveys, the construction of embankments of earth and works of masonry, the construction of highways and the investigation of railway and transportation problems, as would be possible under this bill by assignment to the duties (of the civilians) in the Bureau of Waterways, Geological Survey, Reclamation of Coast and Geodetic Survey, of Mining Technology and of Transportation."

This would indeed be a fine school of practice for the training of experts in military engineering, but it might seem pertinent to inquire what is to become of the many duties pertaining to that Bureau, *ad interim,* when "it is stated by a prominent officer of the Engineer Corps that to properly carry on all the important work now assigned to that corps * * * the personnel should

be increased by at least one hundred officers at once, and this estimate is believed to be too small."

Among the existing bureaus or works proposed to be transferred to this department are the following: The office of the Supervising Architect of the Treasury; the Geological Survey; the Reclamation Service of the Interior Department; the Coast and Geodetic Survey of the Department of Commerce and Labor; the Bureau of Standards; the Superintendence and Care of the Capitol Grounds and Buildings; the powers and duties of the General Land Office in respect to surveys of public lands. There is to be created in addition a Bureau of Mining Technology, to test materials and investigate waste in mining operations; also a Bureau of Transportation, to investigate all matters relating to railway and waterway transfer facilities and the regulation thereof as to sites and location of tracks, grades, bridges, &c., and to exercise oversight as to the terminal facilities of ports; also the office of Public Roads from the Department of Agriculture, to cöordinate the highways of the country with other transportation routes; also the duties now vested in the Inter-state Commerce Commission so far as it has to do with statistics, but leaving all of its judicial functions to another department; also a Bureau of Cöordination to classify, tabulate, compile and publish all data relating to the operation and investigation of the various bureaus and offices of the department and to cöordinate the works of the various bureaus with kindred works in other executive departments, especially with those relating to Irrigation, Swamp Lands, Reclamation, Water-powers, Prevention of Soil Waste and Erosion, Preservation of Forests, &c. It is also proposed that this bureau shall conduct investigations and oversee cöoperative arrangements between the Federal Government and States, municipalities, corporations, &c., which may arise pertaining to the irrigation or drainage of lands, the investigation of mining industries, the oversight of terminal, trackage and wharfage facilities, erection of public buildings, &c. Provision is also made for an Assistant Attorney General and an Auditor for said department.

Such, in brief, is the proposed new element of an already complex Government, having within this department an independent bureau to regulate all related functions, with fiscal and judicial officers, executive and administrative chiefs, and yet unable to execute plans or works unless approved by the chief of the bureau,

the President of the United States and the Congress. To exercise civil power, largely under military control, yet not subordinate to the War Department directly, which powers have not been conferred upon the National Government by the States nor the citizens thereof.

It remains to be noted that this bill places the responsibility of appointing this small army of employees and officials upon the President, and the salaries range from $12,000 per annum for the Secretary, down to that of the lowest employee. The several chiefs of bureaus may have "legal, clerical and special assistants, and such chiefs of divisions, senior clerks, clerks, junior clerks, under clerks, sub-clerical employees, professional and special employees, experts, &c., as may be authorized by law."

The governor of this complicated mechanism is to be the "Commissioner of Cöordination," with a salary of $6000, and an "Assistant Director," appointed by the President, with a salary of $4000, who will be the wheel in the middle of the wheel.

"GOVERNMENT BY COMMISSIONS."

Another measure, far less pretentious, was introduced to vest in the President the authority to appoint an Inland Waterways Commission "to bring into cöordination therewith the Corps of Engineers of the Army, the Bureau of Soils, the Forest Service, the Bureau of Corporations, the Reclamation Service, and other branches of public service related to waterways, and to appoint such experts and other persons and create such board or boards in connection therewith as the work may require, and to fix the salaries of all commissioners, experts and other persons employed under this Act until the same has been fixed by Congress." Such commission shall make examinations and reports, and "if after such examinations, survey and estimate such commission shall determine that any project for the improvement or construction of a waterway is practicable or desirable, it may, with the approval of the President and through the appropriate service construct or execute, or cause to be let, contracts for the construction of the same, &c.," *Provided,* that the necessary moneys therefor are available in the inland waterway fund. This fund is to be supplemented by contributions from States, municipalities, corporations,

&c., and from the sale of reclamation rights, water-powers and other available assets.

Thus all sections of the country desiring improvements of this class would be compelled to besiege the Commission first for examinations, surveys and reports, followed by appropriations, if endorsed, provided there were sufficient funds available for completion. How many years would elapse before a work of any magnitude would be installed can only be determined from past experience, which has demonstrated that from five to fifty years may roll away, and even then the work may not have been begun, because of the superior demand from other and more potent agencies, while projects of no public utility have been approved for political patronage.

The failure of all legislation affecting increased water facilities at the session just closed is evidence of the delays which beset the efforts to conduct such improvements from a single, central source with so many conflicting interests at stake. If the country is to keep pace with the demands for transportation due to its great output of industrial and agricultural products, it is imperative that some radical and liberal legislation should be speedily enacted to stimulate local initiative, as in the pristine days of the Republic.

WOOD PRESERVATION AND THE PROCESS OF PRODUCING CREOSOTE OIL.

One of the significant signs of the times is the awakening of the American people to the dangerous destruction of their forest wealth, and the necessity of a wise use of what remains of it. Undoubtedly, in the future the nation must utilize its forest crop less wastefully, both in the woods and in the mill, and must make provision for future crops; but that is not the only way to prolong the timber supply. If the service of the wood which is used can be lengthened, it will largely decrease the amount of timber which must be cut. And this can be done, by treating the wood with chemicals which will poison the low forms of plant life which attack it and cause it to decay. The growth of timber is slow, and when the dearth of it becomes pressing, a new crop cannot be grown quickly enough to prevent a time of severe shortage. Preservative treatment of timber has the advantage, as a remedy, that it can be applied immediately. Its importance is therefore attracting increasing attention.

Many chemicals have been used for the preservation of timber, among them being blue vitriol, corrosive sublimate and chloride of zinc. The

most effective preservative is the substance called "creosote oil," or "creosote." On account of the similarity of the names, many people suppose this to be the creosote obtained from wood, such as can be obtained, refined for medical purposes, at the drug stores. But the two are quite different, and should not be confused. The creosote used in wood preservation is obtained from coal, by a most interesting process.

Nearly every city now uses gas for light and fuel, and many people know that this illuminating gas is often made from coal. But the many things besides gas which are obtained in this process are not so well known. It is one of these other products from which is obtained the creosote oil used for wood preservation.

To understand how all these things are produced, it is necessary to know something which the chemists can tell us. Coal, they say, is composed partly of the substance called carbon, partly of compounds of this carbon with the gas hydrogen, which they have named "hydrocarbons." When the coal is heated sufficiently, away from air, the hydrocarbons are driven out in the form of gas. Illuminating gas is made by subjecting coal of the proper kind to this process, which is known as "dry distillation." The coal is put into a long, fire-clay oven, or "retort," shaped much like a giant model of the little cakes which the bakers call "lady fingers," the retorts being about thirteen feet long, two feet wide and sixteen feet deep. A number of these retorts are built side by side, in three rows, one above the other, the ends of the retorts being supported in a brick wall, which also extends around the ends of the rows and over the top, and thus entirely encloses the retorts. Fire, from furnaces below, is carried by flues into this enclosure, so that the retorts are entirely enveloped in flame and can be heated to a very high temperature.

The retorts are partly filled with coal, after which they are sealed, so that no air can get into them. They are then heated to a temperature of about 2,100 degrees, F. Under this intense heat almost all the hydrocarbons of coal pass off, leaving behind only the "fixed" carbon, which comes out of the retort as coke. Many of the lighter compounds distilled off by the heat now remain in the form of gas when they are cooled to ordinary temperatures, and it is some of these which make the gas finally used for lighting and fuel. But as it comes from the retorts the gas is like a thick, yellowish-green smoke, and could not be used at all for such purposes. This gas escapes from the retorts into a series of large and costly machines where the lighter gas is cleansed from its impurities, and the different by-products are separated from each other. First are great "condensers," in which the gases are cooled. The cooling condenses the heavier compounds into thick liquids, which are then left behind.

One of the substances later removed from the gas is ammonia, and from such gas works comes the ammonia water which is used in every household. Another important product of the gas making process is the coke which is left in the retort. Every year an increasing number of people use this coke for burning in kitchen stoves, and even in furnaces, instead of coal, for it makes a very hot fire and burns without any smoke.

The heavy, strong-smelling, black liquid which is collected in the cooling

of the gas is what we know as coal tar. This is an exceedingly complex mixture of substances. From it are obtained not only creosote oil, but most of the dyes which are used now-a-days, perfumes, and even flavoring extracts.

Gas, coal tar and coke are also made in what is known as the by-product coke oven, which is adapted to different objects, but is operated on the same principle. Its coal tar is equally as good as the gas works tar for making creosote oil. In recent years a great amount of gas has been made in the United States by another process, and is known as water gas. This process also produces a tar, which looks much like coal tar and is often difficult to tell from it. But this tar is really derived from petroleum, and does not make a good oil for preserving wood from decay. Wood creosote, with which so many people are familiar, is likewise obtained from a wood tar, which is produced by distilling wood. But like water gas tar creosote, wood creosote is not so good for wood preservation as is the coal tar creosote. When creosote is bought for that purpose, therefore, it should be certain that it is coal tar creosote.

To obtain creosote oil from coal tar, the tar is, in turn, distilled. But this distillation is like that used for other liquids instead of that employed for the coal. The still is heated, and as the heat increases the "light oils" first pass over. Among these is the familiar carbolic acid. This is a powerful antiseptic, but it is not desirable in a wood preservative, for it evaporates so readily that it soon becomes lost from the wood. When a temperature of about 400 degrees has been reached, the distillate is turned into another receiver, and from this point on to 600 or 700 degrees creosote oil is produced. One of the substances which is contained in this mixture is "naphthalene," from which common moth balls are made. Coal tar creosote, thus produced, is the great wood preservative.

The residue remaining in the still after the distillation is "pitch," which is used chiefly in the preparation of roofing felt. In America roofing pitch is the chief end for which tar is distilled. In Europe this is not so true. Now pitch for roofing must be rather soft. Therefore tar distilllation is not carried so far in this country as it is in Europe. For creosote oil it would be better if it were carried farther, since the substances which distil at the higher temperatures, in most cases, neither evaporate in the air nor dissolved in water as readily as those which distil more readily. Consequently they stay in the wood for a longer time, and protect it correspondingly longer from decay. Much study has been devoted by the United States Forest Service to creosote oil, to determine what its composition should be to give the best results in preserving timber, under different conditions, and how the most desirable creosotes may be obtained. The reports of these studies, together with detailed description of the more economical processes of applying the preservatives to wood have been worked into circulars which the Government has placed at the disposal of users of timber and which will be furnished to all who make the request of the Forester at Washington.—*Bureau of Forestry—U. S. Dept. of Agriculture.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 3 83RD YEAR SEPTEMBER, 1908

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

(Stated meeting held Wednesday, April 15, 1908.)

The Theory of Shooting and the Evolution of the Spitzer Bullet.

BY L. H. HARTMANN.

Graduate of the Schuetzen Schule, Spandau, Germany.

A knowledge of the fundamental laws governing the flight of the bullet fired from a rifle—the theory of shooting—while it is a necessity for the gun-makers and the gun-experts, ought to be also possessed by every shooter. The person possessing this knowledge, all other things being equal, will be superior in marksmanship to the one not acquainted with these fundamental laws. A proper teaching of the theory of shooting ought to be the foundation upon which to develop the greatest percentage of marksmen—of good shots.

The flight of the bullet from the muzzle to the point in its flight, where it loses the power imparted to it by the explosion of

the powder, is called trajectory. The length of the trajectory, in the main, is determined by the relative proportion of the weight of the projectile to the strength or expansive power of the developed powder gases. The bullet loses its power after leaving the muzzle, first "by the law of gravity," and second, by "the resistance of the air."

In order to overcome, or rather counter-effect the fall of the bullet, we elevate the muzzle by means of the difference in elevation of front and rear sight. The second we try to minimize, as much as possible, by rifling the barrel and shaping the bullet.

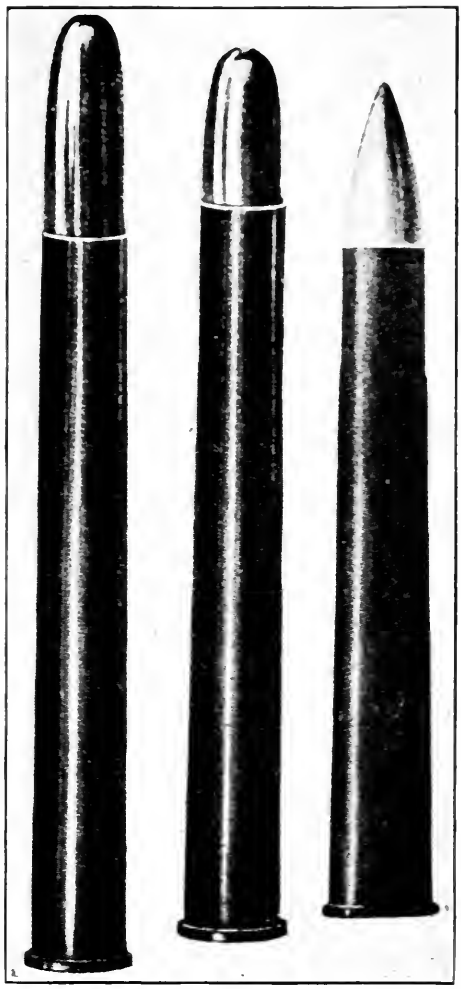
The law of gravity is a well known quantity. The bullet, from the moment it leaves the muzzle, falls at the square of the odd numbers; that is, it falls 16 feet, approximately, in the first second, it falls 3×16 feet in the second second, it falls 5×16 feet in the third second. Consequently, if we did not elevate the muzzle over the horizontal line, we would have to fire the rifle from a height of sixteen feet in order to hit a point perpendicularly below on the ground at the end of the first second of the flight of the bullet. In order to hit the same point at the end of the second second of the flight of the bullet, we would have to mount a scaffold $3 \times 16 + 16 = 64$ feet in height. At the end of the third second the scaffold would have to be $5 \times 16 + 64 = 144$ feet in height. This shows the necessity of accelerating the flight of the bullet as much as possible. Upon the space traversed in the first second, which we call the initial or muzzle velocity of the bullet, depends, in a large measure, the efficiency of the bullet.

To overcome the effect of gravitation upon the bullet, we elevate the muzzle by making the rear sight higher than the front sight. This creates an angle between the line of sight, formed by the eye on one end and looking in a straight line over the rear sight and front sight with the point aimed at at the other end, and the imaginary line drawn through the exact center of the barrel and elongated. The projectile follows this imaginary line just as long as it is in the barrel, but the very moment it leaves the muzzle the law of gravitation acts upon it and it falls, that is, it leaves the continuation of the imaginary center line of the barrel. The angle between the line of sight and the center line is formed the nearer to the muzzle of the rifle the higher the elevation of the rear sight.

The trajectory takes the form of an elongated, parabolic-curve,

which can be aptly illustrated by the outline of a hen's egg cut in half. The trajectory is divided into two parts, the one nearer to the muzzle being called the ascending arm, the one nearest the point aimed at the descending arm. The ascending arm forms about two-thirds of the length of the trajectory.

There is but one trajectory, and that is the one at the distance



No. 1. No. 2. No. 3.

where the bullet ceases to have any power except the power of its own weight. This is important to keep in mind, for, whether we speak of a trajectory at 50 yards, at 150 yards or at 1000 yards, they are all a part of the same long trajectory only produced by stopping the flight of the bullet by an object interposed at a certain point in this never-varying flight.

The ascending arm of the trajectory rises to a certain point over the line of sight at a given distance and this highest point is

called the elevation. In speaking of a high or low trajectory we mean the highest point of that trajectory over the line of sight. The parts of the trajectory where the elevation is not greater than the size of the object aimed at is called the "danger zone." If, for example, you aim at a deer standing still, you have to judge the distance. We will say you judge this distance to be 150 yards. If you have a rifle where the elevation of the trajectory is 24 inches, you will have to judge very accurately, for if that deer happens to stand at 120 yards instead of at 150 yards, you are very apt to miss him by overshooting, or, if he stands at 170 yards, by undershooting. If, on the other hand, you have a rifle with a low or flat trajectory, say, for example, of nine inches elevation, you will hit that deer at any distance from you up to 150 yards, providing you aim at the belly part of the body, a deer presenting a killing surface of about ten inches.

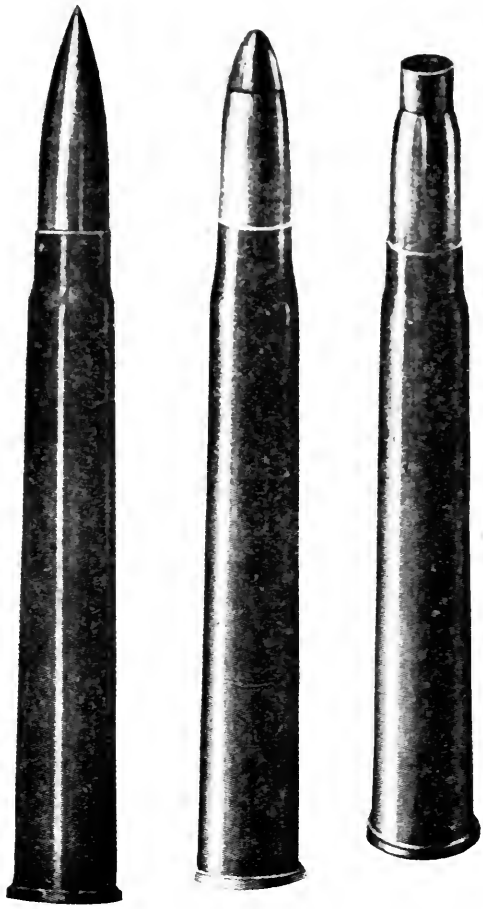
The practical solution of the effect of the law of gravity upon the bullet is, as we have seen, easy. The practical overcoming of the resistance of the air is an entirely different and much more difficult matter. In my introductory remarks I said that we try to overcome the resistance of the air by rifling the barrel and shaping the bullet.

The first projectile of which we have any knowledge is a round ball of lead, whose sphere fitted the bore of a smooth barrel. If the ball did not fit, it was patched by a piece of greased cloth.

It was soon evident that, in order to produce results, we had to impart to the bullet a boring motion and also make it as light as possible. But in putting a twisted rifling into the barrel, while we imparted a screw-like motion to the bullet during its flight through the air and thereby enabled it to overcome the resistance better, we also greatly intensified the effect of the bullet's own center of gravity upon its flight. This effect of the center of gravity upon the flight of the bullet has forever been the bugbear of riflemakers. It threads its way through the whole history of the bullet, from its inception in the round ball to the present pointed bullet.

At first there was no proviso for upsetting the ball in the barrel, the ball being seated directly on the powder. The least irregularity in the sphere of the ball would let powder gases escape alongside of it. It is of common occurrence to-day for a gunmaker to be called upon to take the breech-pin out of a barrel

and find it nothing but a plug against which powder and ball rested, with just a vent for the entrance of the flash produced by the explosion of the powder in the pan or the percussion cap. The next step forward was the elongation of breech-pin so as to contain a receptacle for the powder with a rounded concave place for the ball. By seating the ball firmly with the ramrod it would spread until stopped by the sides of the barrel and thus produce an even fit.



No. 4. No. 5. No. 7.

This principle was employed until the breech-loading rifle superseded the muzzle-loader. The first known were straight grooves cut lengthwise into the barrel; this was done to enable the shooter to use both shot and ball in the same weapon. But the guiding power of the rifling upon the ball was very small on account of the small amount of contact between a round ball and the barrel; and the ball, after leaving the muzzle, would play all

kinds of pranks in finding its own center of gravity or equilibrium.

When we think that these balls were all cast in a mould, that this mould would enclose an amount of air, part of which would invariably be imprisoned in the wall without any way to determine where it was; when we think that in a ball, twelve to the pound, and which is a little over three-fourths inch in diameter, this air-hole might be clear to one side, you can readily imagine the funny motions of that ball in the air when it jumps around this eccentric-hole in the inside.

The uselessness of the ball was too apparent for it not to be soon abandoned.

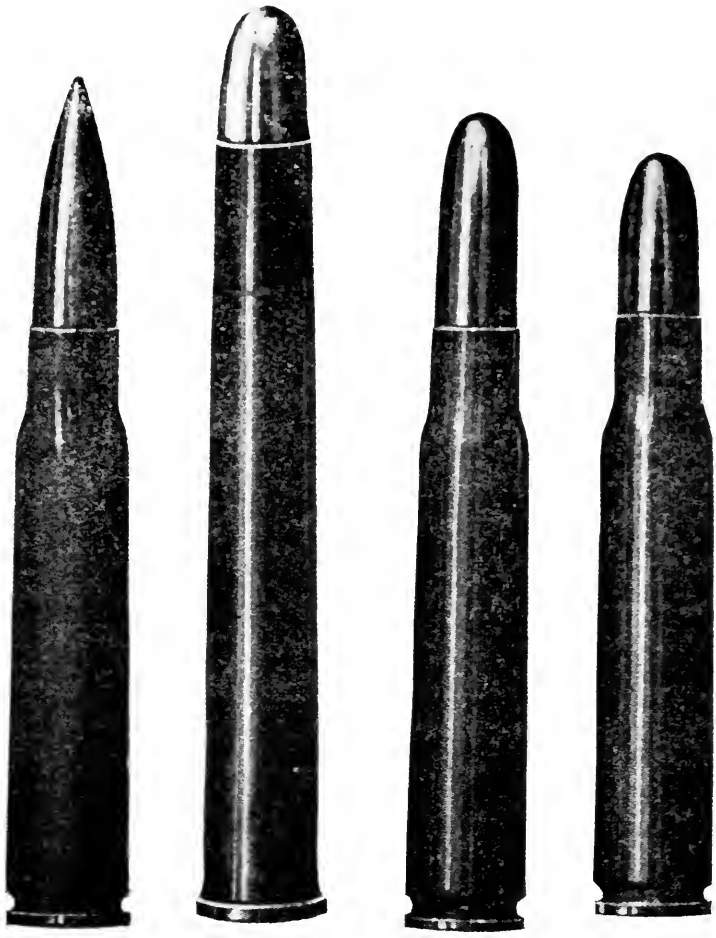
In order to make the rifling effective it was necessary to create more contact; this led to the elongated ball—the bullet—and the diminution of the bore or calibre. If we talk of a bore we mean a barrel, the diameter of which is adapted to a ball, a given number of which make a pound in weight; if we talk of caliber we mean a barrel the diameter of which is expressed in inches. It is therefore proper to say, "A 12-Bore Gun" and "A 32-Cal. Rifle."

Shot-guns are made in bores from 4-bore to 28-bore, also called gauge; that means that the diameter of the true sphere of a ball weighing one-quarter pound or four ounces means a 4-bore or gauge, while the same relative measurements obtaining to twelve balls in a pound would mean 12-bore or gauge, etc. The diameter of the true sphere of a 12-bore gun-barrel is .729 inches.

But the elongated bullet, while it offered a smaller front for the action of the air, still was just as freaky as the ball, for that little aforementioned air-hole might be in the extreme end of it, and the bullet, instead of flying straight, would describe a series of somersaults in the air, alongside of which the performances of Barnum's best clowns sink into insignificance.

The desire to force the bullet to fly in the direction imparted to it by the barrel created the twisted rifling. A great step forward had been accomplished, for not only had the gunmaker succeeded in forcing the bullet to revolve around its own axis, and thereby minimize the effect of the center of equilibrium, but the resistance of the air was materially reduced, especially as the improvements in the methods of rifling allowed the reduction of the weight and the diameter of the bullet. With the introduction of the stud into the breech-pin the maximum of efficiency in muzzle-loading

rifles was reached. This stud was a pin screwed into the exact center of the breech-pin and entering for the length of about 1½ inches into the barrel. The flat end of the bullet would meet this stud, and by tapping with the ram-rod, would spread the bullet to fill out the grooves evenly. The open space between the bullet and the end of the breech-pin allowed the powder charge



Nos. 11, 12 & 13. Nos. 3 & 4. No. 6. Nos. 8 & 10.

to be changed *ad libitum*. This method, however, was only adopted where there was ample time for loading, and was therefore employed mainly for target-rifles. The degree of accuracy, however, obtained by these rifles up to 400 yards is astonishing.

We now enter the era of the breech-loader. When Dreyse, of Locmerda, Germany, invented the needle-gun, the muzzle-loading rifle had been developed to a high degree of efficiency, and the theory of shooting was well known to this inventor. His main

aim was to overcome the unevenness in the burning of black powder. For when black powder is ignited from the rear end of the powder volume, its ignition being slow, it develops sufficient gases to drive the bullet out of the barrel before all the powder had been ignited. The injurious effect of this uneven ignition upon the accuracy of flight of the bullet is apparent. In the muzzle-loading rifle with the breech-pin stud this had been overcome almost entirely by the fact that the powder was lying loose in a sort of chamber, and, as a matter of course, ignites quicker and more evenly. But powder could not be carried loose in fixed ammunition. Dreyse overcome this by placing the fulminate in front of the powder column, in the center of a paper cylinder, which was about one inch in length, and the other end of which formed a cavity which contained the bullet. This bullet was elongated with round ends, the front end being slightly more pointed. This bullet being smaller than the caliber of the rifle, never touched the inside of the barrel, but received its impetus from the paper cylinder. The needle penetrated the powder column the whole length, and pricking the fulminate, ignited it. As there was no chance for any powder not to burn before the bullet left the muzzle, the accuracy of this weapon at short range was very great, in fact, at short range it has never been surpassed by any rifle shooting a cartridge loaded with black powder. But at ranges over 300 yards the bullet went wild. On account of the shell being made out of paper, however, this style of cartridge never found much favor in either military or sportsmen's circles outside of Prussia.

An enormous stride forward has been made; we had the breech-loading rifle, and soon came the brass shell. As a matter of curiosity it may be remarked, that in the infancy of the brass shells a great many gunmakers shook their heads dubiously, for results with these shells were not easily obtainable, on account of the fact that a new factor had to be taken into consideration. For, following the physical law of the mutability of bodies, the bullet would upset; that is, on account of the suddenness of the shock, the front part of the now well elongated bullet would be still while the rear part was already in motion. This same effect is produced, for example, on a center-punch or a chisel in the upsetting of the head. In the muzzle-loading rifle this did not have any effect, for the bullet was contained by the rifling; but in

a breech-loader this at first proved a serious drawback, for the exact size of the bullet was not easily obtainable. Many a first-class rifle-maker has given up the making of breech-loading rifles in despair; a few of them, however, helped themselves in a curious way. They would make a steel shell; the inside of this shell was smaller than the caliber of the rifle and projected into the rifle in exactly the same manner as in the muzzle-loading rifle. The bullet was inserted from the muzzle, usually with the help of a false muzzle, and with a ram-rod seated on the projection of the steel shell. It is noteworthy that this same method is employed

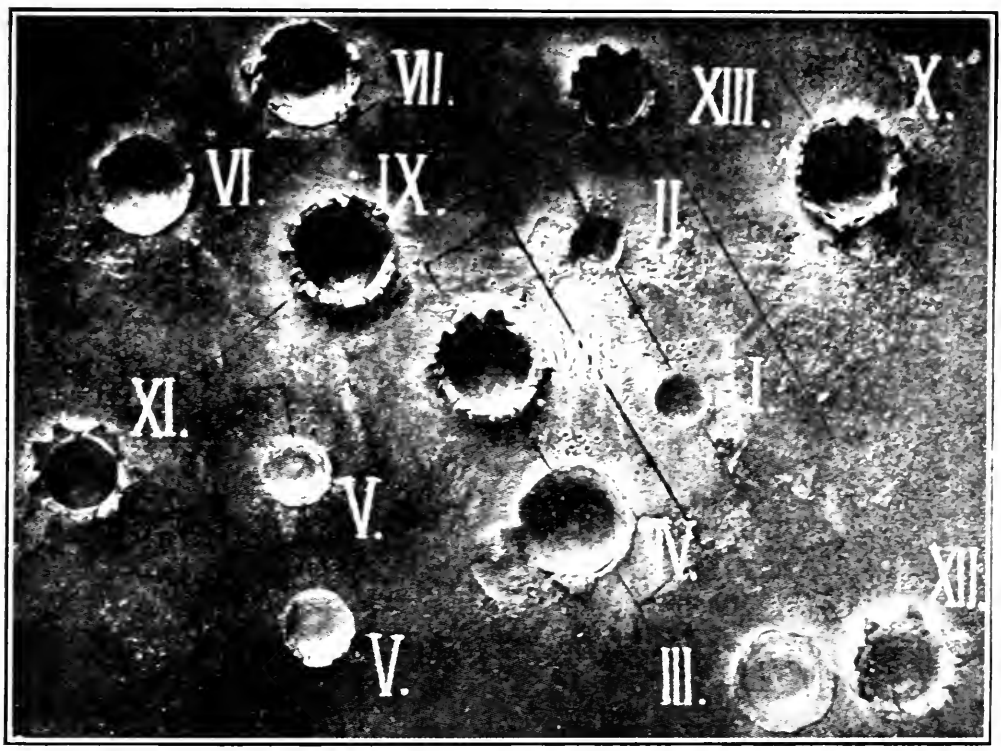


Plate No. 1.

to-day in target-shooting, where time is plentiful. While the results obtained in this manner were very satisfactory as far as accuracy was concerned, they were of course useless for military or hunting purposes. It has taken a comparatively long time to ascertain the exact size of a bullet and the relative difference between the diameter of a bullet and the caliber of the rifle, for which it was intended. The density of the lead employed would alter the size, and as soon as this was apparent, the casting of bullets in a mould was abandoned and the bullets were made

out of lead wire of equal density drawn to size and stamped or pressed. As these bullets were without air-holes from casting, their center of equilibrium came to be as nearly in the same place as mechanical ability could make it. Breech-loading rifles commenced to shoot with surprising accuracy.

One element, of which I have not yet spoken, is the natural drift of the bullet, not the drift produced by the action of the wind. With the twist of the rifling the bullet would drift in the same direction. This was, however, not the only influence. The modus of fastening the sights, the fastening of the receiver and other like things would make the bullet drift. How intense these influences would act is illustrated by the following episode: When the German Government, after the victorious war of '70-'71, wanted to equip its army with the new Mauser rifle, known as Model 6, 1871, it pressed the gunmakers of the world, except the French, into its service. Birmingham, in England, held large contracts. And while all the parts, as well as the finished rifle, were inspected and proved in Birmingham by German officials, the finished arms were sent to the Government factory, Spandau, for their final shooting test. I happened to be a pupil at the Government shooting school, when it was discovered that out of a shipment of 1000 rifles from Birmingham over ninety per cent. would shoot to the extreme right. Here was a puzzler, for all of the proof stamps were on the rifles, the barrels were straight, the caliber exact, etc. Finally it was decided to test the material in the barrel. When the rifle was brought into the factory to have the receiver unscrewed from the barrel, it was found that they were screwed on exceedingly tight and had strained the metal in the barrel. This caused the drifting, and as soon as this strain was removed the shooting quality of these rifles proved to be normal. There are numerous little mechanical defects which cause the bullets to drift, such as rust spots, unevenness of muzzle, etc.

So far all the projectiles were made out of lead. But the usefulness of lead was limited by the fact that the moment you wanted to increase the muzzle velocity over a given point by increasing the powder charge, the developed force was too great for the softness of the material and the bullet would strip; that means it would not follow the rifling, but be driven straight through the barrel. This led to the moulding of the bullet with copper and

lead, the foundation of the present projectile Still the trajectory showed high elevations:

This was changed, however, with the introduction of smokeless powder by Noble. Here was given an explosive force of hitherto unknown power, which, when reduced to safe standards, bade fair to fulfil the dreams of the gun experts as far as flatness of trajectory is concerned. While at first the construction of suitably strong rifles offered some obstacles, these were soon overcome by the combined efforts of the theoretical and the practical men. Nickle was substituted for copper, steel for lead as a core. The riflings were changed in all kinds of ways, until finally there was

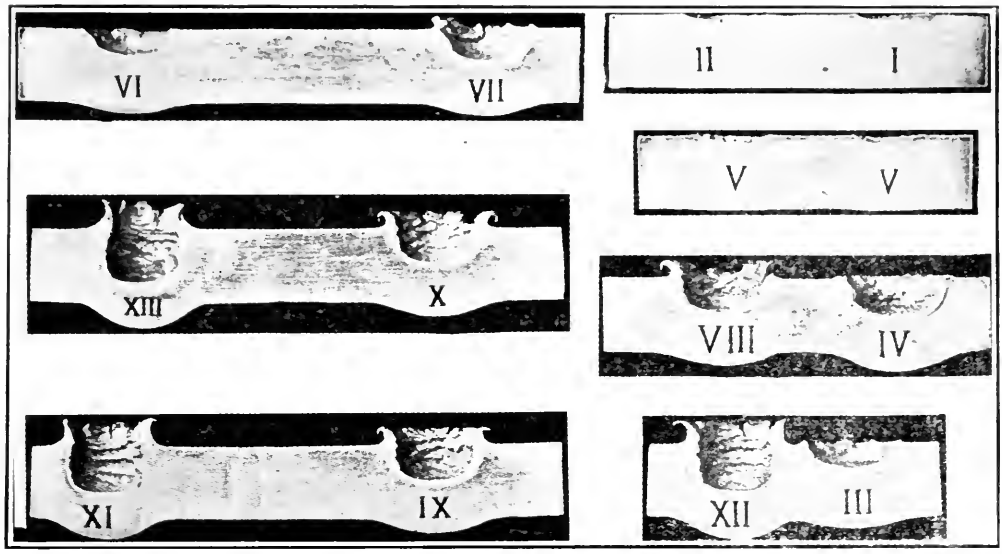


Plate No. 2.

produced the ideal bullet, the sharp-pointed bullet, the Spitzer, which, owing to the fact that it offered the least resistance to the air, and through its perfect balance gives results in accuracy which are very gratifying to the ordnance officers of the army, as well as to the hunter and the marksman.

So marked is the difference between a round-nosed bullet and a Spitzer that the muzzle velocity produced by the same charge in our present Government rifles is 2000 feet in the first second by the round-nosed and 2800 feet by the Spitzer with a gas pressure of 42,000 pounds per cubic inch.

HARTMANN'S PAPER.

The accompanying table gives the number of cartridge, the caliber in inches, the weight of the powder charge in grains, the composition and weight of the bullets and the muzzle velocity of the bullets in feet per second.

Plate No. 1 gives the size of the orifices made in a wrought-iron plate by each bullet fired at the same distance; the orifices are all numbered to correspond with the number of the cartridge in the table. Plate No. 2 shows the depth of penetration in the same iron plate; each orifice in this plate is also numbered to correspond with the number of the cartridge in the table. For instance, cartridge No. 3, calibre .365, loaded with 56 grains smokeless leaf powder, full steel jacket, bullet weight 225 grains, with a muzzle velocity of 2,355 feet per second, made orifice No. 3 in plate No. 1, and penetrated to the depth of orifice No. 3 in plate No. 2.

DR. W. O. GRIGGS.

Cart'ge No.	Caliber Inches.	Powder Charge.	Bullet composition and weight.	Muzzle velocity.
		Black Powder.		
1	.365	54 grs	Soft lead....211.2 grs	1471 ft. per sec.
2	.365	54 grs	Hard lead....206.1 grs	1500 " "
		Smokeless Leaf Powder.		
3	.365	56 grs	Full Jacket ..225 grs	2355 " "
4	.365	60 grs	" " 225 grs	2446 " "
5	.315	40.5 grs	" " 220.5 grs	2003 " "
6	.315	43.5 grs	" " 187.5 grs	2380 " "
7	.315	45 grs	Part " 150 grs	2573 " "
8	.315	45 grs	Full " 144 grs	2676 " "
9	.315	46.5 grs	" " 144 grs	2738 " "
10	.315	48 grs	" " 144 grs	2733 " "
11	.315	45 grs	Spitzer.....394 grs	2676 " "
12	.315	46.5 grs	" .....394 grs	2774 " "
13	.315	48 grs	" .....394 grs	2791 " "

PRODUCTION OF CRYSTALLINE QUARTZ AND FELDSPAR IN 1906.

In an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," Douglas B. Sterrett, geologist, of the United States Geological Survey, reports that the production of crystalline quartz and feldspar in the United States in 1906 amounted to 20,082 short tons, valued at $121,671, as against 19,039 tons, valued at $88,118, in 1905, an increase of 5043 tons in quantity and of $33,553 in value. In quantity the production was exceeded only by that of 1903, which was 31,940 tons, while the value was greater than for any previous year. There was a large increase in the output of abrasive feldspar, which forms an important part of the total production. The crystalline quartz output was reported by three producers in Connecticut, one in Pennsylvania, and one in Wisconsin. Mr. Sterrett's paper contains a table showing the production of this abrasive since 1895.

(Stated meeting held Wednesday, June 17, 1908.)

Latest Developments in the Burroughs' System of Book-keeping and Accounting.

Development of the Accounting Machine.

By R. L. Burd.

On behalf of the Burroughs Adding Machine Company, I desire to thank the Institute for the privilege of addressing you this evening on the subject of the Adding and Listing Machine as we know it to-day.

The idea of a commercial machine to add and list figures was original with William Seward Burroughs. The idea occurred to Mr. Burroughs when he was a bank clerk in Auburn, New York, and on account of poor health was ordered by his physicians to give up close, confining work. Believing that it was largely this work which had ruined his health, Mr. Burroughs set about devising a machine which would do the routine work of the clerk; and the rest of his life was devoted solely to this object.

In 1882 he went to St. Louis and began to put his ideas into definite shape, a task which occupied him constantly until he finally developed a practical model in 1889.

Like many inventors, Burroughs did not have money to carry on his experiments, and at an early stage in the development of the machine was obliged to hunt for capital. In this he was met by constant disappointment, as many people looked with suspicion upon a man who was so foolish as to think that he could make a machine do the work of the human brain, and as a result he was often considered somewhat out of his mind.

The very first models which Burroughs made are not in existence at the present time. The first one of which we have any definite record was very crude and had to be abandoned after tests had proven that it was not capable of doing the work required. It

is notable, however, that even in his early models, Mr. Burroughs included many of the essential features of the machine as it is built to-day, and it is a wonderful comment on his ability that after twenty-five years of practical tests it has been found that the original principles, as laid down by Burroughs, cannot be improved upon—and, in fact, have never even been approached by those who have spent years in the study of this subject since the time of Burroughs.

Mr. Burroughs' first aim was to produce a machine that would record figures on paper and would give a correct total of the amounts that were printed, without depending in any way upon human agency, except for the operation of the keyboard. The greatest trouble which he experienced was in getting his printing mechanism to work in exact unison with the totalling mechanism, and eventually he solved this problem by making the two mechanisms integral. This is the famous Burroughs Pivotal Principle. The entire mechanism for printing and adding amounts is mounted on one bar—a bar for each column of figures. The sector teeth, which perform the addition, are placed at one end of the bar, and the type, which perform the printing, at the other end. These bars swing on a central shaft or pivot, and the operation of the machine, therefore, is performed by a simple rocking or "see-saw" motion of these bars.

Other features which Burroughs devised to accomplish the work he had in mind are Locked Keyboard, which prevents the operator from depressing more than one key in any one column without first pressing a correction key; the locked adding mechanism, which keeps the total wheels positively locked at all times, insuring that only those amounts which are depressed in the keyboard shall be printed and added; the hammer printing mechanism, by which the type are fired against the paper, one at a time, doing away with vibration and jar. One essential principle which Burroughs at first overlooked, was the device to control the operation of the machine and guard it against rough treatment on the part of the operator. The necessity for this device was not discovered until the first machines were placed upon the market and subjected to the final test of commercial use.

It was in 1889 that the first machine was placed in the hands of the public, and its development at that time represented an expenditure of more than $300,000. Mr. Burroughs considered the

machine perfect in every respect, because, in operating it himself, it responded perfectly and seemed to have no faults. The machines placed upon the market, however, being in the hands of inexperienced operators, soon gave trouble, and Burroughs found it necessary to visit the different users of the machine, when he discovered that there was a great difference between the machine when operated with his own hands and by careless and unskilled operators.

This was perhaps one of the worst disappointments in all the long series of disappointments which Burroughs experienced in his work. He had reached his triumph as the inventor of the first commercial machine to do this work, and here he was confronted by the failure of the machine, due not to any fault of the

Burroughs sector bar, carrying adding teeth at one end and printing types at the other. The operation of the machine is performed by the rocking, or "see saw" motion of these bars one for each vertical row of keys. When the adding mechanism descends a certain number of notches, the printing mechanism must rise an equal distance, so that whatever is added must be printed.

machine itself, but to the fact that it was impossible to train all of the people who might be called upon to use it.

He wrestled with this problem for a long time, and his final solution was the Burroughs Controlling Device, which consists of an automatic governor located centrally in the machine, absolutely controlling its functions and safeguarding the mechanism against rough usage of any kind.

The machines that had been sent out for public trial were now recalled, and as they were received, one at a time, at the old Boyer machine shop, where Burroughs built his first machine, Mr. Burroughs took them in hand and stored them away in a small room in the work shop. When all had been returned and replaced by machines containing the controlling device, the inventor quietly

went to this room one day, without telling anyone his intentions, opened a rear window and tossed all the machines, one by one, out into the paved court yard, where they were heaped up in an unrecognizable mass of material. He then went to the shop and called Mr. Boyer out into the back yard, saying, "I have something to show you." Pointing to the pile of scrap iron, which was all that remained of his early work, he said: "There, I have got rid of all my troubles." This instance only shows the love for accuracy which Burroughs had, and which is shown today in his machine. So painstaking was he in all his work that even his drawings were made upon metal plates in order to gain absolute accuracy.

After the controlling device had been placed in the machine and its efficiency established beyond a doubt, the success of the company was assured, and 1,000 machines were built and sold between the years 1891 and 1895. Perhaps the best demonstration of the thoroughness of Burroughs' work is shown by the fact that some of these very first machines are still in use to-day and are perfectly accurate in every way.

The constant increase in the demand for the Burroughs machine is shown by the fact that while it took four years to sell the first 1,000 machines, the sales for the year 1907 alone were 13,314 machines, and there are over 65,000 in use at the present day.

In 1904 the first factory, which was built in St. Louis, for the manufacture of the machine was outgrown, and the American Arithmometer Company, as it was known at that time, moved to Detroit, where a new factory was built providing sixty per cent. more floor space than the former one. The name of the company was also changed at this time to the "Burroughs Adding Machine Company." In addition to moving the machinery and equipment, the company moved its skilled employes, their families and furniture, from St. Louis to Detroit. This factory in Detroit is located on a beautiful, broad, shaded boulevard, and is a model for cleanliness, light, modern appointments and completeness. At the present time the company are planning a building for office use alone which will give them a continuous frontage on the boulevard of two city blocks, with a total floor space in factory and offices of over five acres.

In order to meet the constantly enlarging demands of business,

it is necessary to maintain an Inventions Department, comprising over 100 skilled men—inventors, designers, draughtsmen, and experimental mechanics—who are working constantly bringing out new ideas and enlarging the scope of the machine. It seems remarkable, when we stop to think, that this corps of inventors, including the best minds in the adding machine art, that the fundamental principles contained in Mr. Burroughs' experimental machines, still command the admiration of the best mechanical engineers of to-day.

The pivotal principle is, of course, responsible for much of the success and prestige of the Burroughs machine. This is readily understood, as the friction in the pivotal bearings is very slight, whereas the sliding, dragging, metal-to-metal bearing surface used in most tpyes of machines involves a constant sliding back and forth, which, of course, discharges oil from the bearings in a short time. It is said by those who were acquainted with Mr. Burroughs when he began his work, that he tried a sliding principle at the start, but could not secure accuracy, and found that his results could only be accomplished by using the pivotal principle.

The type bar, or sector, on the Burroughs machine carries the type figures from "naught" to "nine" on its rear end, and the adding rack on its forward end. The machine is constructed so that this bar moves at a high rate of speed with little friction, and to make this possible its weight is supported by the bearing on the center shaft, the bar being perfectly balanced. This not only secures ease of operation, but allows a movement of two or three inches at the ends, with a bearing movement of but 3/32 of an inch, in handling the largest amounts.

The entire machine is constructed on this pivotal principle, and every moving part works on a pivotal bearing and swings in the arc of a circle.

Regarding the controlling device which I have mentioned: In addition to the oil actuated controller, we have two heavy springs which take up all vibration and jar imparted to the machine by means of the handle. In other words, the power applied to the handle is transmitted to the machine through these springs and the controlling device, so that no matter how hard or fast the handle may be pulled, the machine cannot go above the normal speed, and the sequence in which its functions are performed cannot be

disturbed or altered in any way. It will be seen that such perfect control is necessary in a machine which does the work of the Burroughs, for while a watch may vary two or three seconds in the course of a day without disturbing its owner, the Burroughs must not vary a single unit in its tireless daily grind of figures. Therefore, whether the machine is operated fast or slow, by an operator who pulls the handle evenly, or one who jerks it violently, the machine is bound to give the same results in each instance. Therefore, the life of the machine is not determined, or in any way shortened, by the manner of its operation.

Next, Mr. Burroughs realized that it was necessary to securely lock the adding wheels in the front of the machine at all times, and the safeguards thrown around this adding mechanism are perfect. As the handle is pulled forward preparatory to adding an amount, these adding wheels must move out to permit the adding sector to descend, and as the wheels move out they are locked between two teeth in front before they are unlocked in the rear from the teeth in this adding rack. By this you can see that no shock or jar could ever be great enough to disturb the figures on these wheels, which show the correct total at all times.

Next, Mr. Burroughs realized that vibration must be avoided if the machine was to perform its work perfectly and for a long time. Therefore, he did away with vibration in all parts of the machine. In addition to the shock absorbers which I have previously described, he carried out the same idea in the printing mechanism by causing the hammers which perform the printing to strike one at a time, instead of all at once. In the standard sized Burroughs machine there are nine of these hammers, and they fire one at a time, the effect being as though we were to fire a double-barreled shot-gun one barrel at a time instead of both together.

Another thing which Mr. Burroughs provided for was an absolutely interchangeable construction throughout the Burroughs machine. A part which becomes slightly worn after years of use can be replaced with a new one without hand work or special fitting, and this is possible, because Mr. Burroughs constructed the machine in such a way that every part is easily accessible and interchangeable. To maintain this interchangeability it is necessary to have very fine and accurate instruments, and thus the tool room at the Burroughs model factory is one of the best equipped in the

country and employs nearly 200 skilled mechanics, who are very busy turning out the various tools used in the manufacture of the machine.

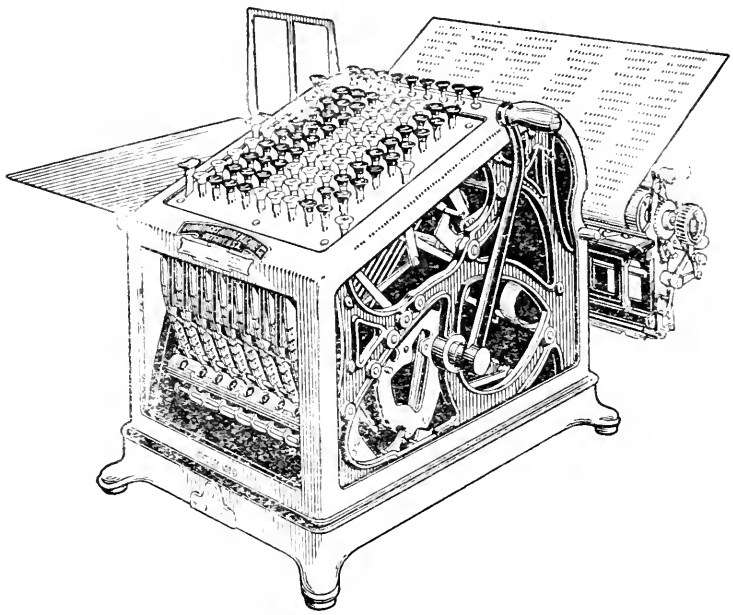
The Burroughs machine is sometimes criticised on the ground that it contains so many parts, but the wonderful length of life of the machines in constant use proves conclusively that there are only enough parts to make a perfect machine for a long length of time. In this connection we might compare two watches, one made to sell for a dollar, the other a good Swiss or American made watch. In the good watch we have more parts, more springs, but we have accuracy and long life. In the other we have fewer parts, also a constant doubt as to the accuracy of the watch, and very short life. In the dollar-watch the number of parts has been reduced to bring the manufacturing cost within the required limit. This makes it necessary for each part to perform the work that should be borne by two or three, and in doing this that part is subjected to great wear, which soon destroys its accuracy.

Mechanical Accounting.

By Thomas M. Jones.

When Mr. Burroughs was endeavoring to raise enough money to perfect his invention, the greatest inducement he had to offer to his prospective backers was that some day they might be able to sell as many as 8,000 machines to the banks in this country. At the present time there are over 65,000 Burroughs machines in use, and hardly one-third of these are used by banks. The first machines that were sold were fitted with a paper carriage to accommodate a roll of paper only. This, at that time, being the only style of paper desired by banks, whose use for the machine was simply making their balances. The first need for a paper carriage to accommodate wide sheets was made apparent by the needs of cotton dealers, who found that they could save a great deal of time by invoicing their cotton weights on the adding machine. Cotton weight sheets were so ruled as to accommodate the weights of one hundred bales. The wide paper carriage was

then devised for this work, and its uses are at the present time almost unlimited. The idea is almost general in the minds of those not conversant with the many uses of the adding machine, that its field is limited almost exclusively to the requirements of the banker. The fact, however, that hardly one-third of the machines in use at the present time are in banks conclusively disproves this idea. Adding machines are now in use extensively by the manufacturer, jobber, retailer, railroad and insurance, and gas and electric companies, and the cotton, oil and coal businesses, dairies, private residences, municipalities, and the United States



Regular model Burroughs adding and listing machine, capacity 999,999,999, equipped with typewriter carriage for tabular work on broad sheets, ledger leaves, etc., up to 18 inches wide. Burroughs are built in fifty-eight different styles, for hand or electric operation, with capacities up to 999,999,999,999,999

Government, and are conspicuous by their absence in any up-to-date business establishment.

The adding machine's work in the bank compares very closely to its work in mercantile concerns. The banker is really a merchant who deals in money for which he pays a certain rate of interest, and sells at a profit of from three to ten per cent. A check represents an order for money just the same as a salesman's order is a requisition for merchandise. In banking establishments adding machines are used for balancing the teller's cash, making out remittance letters, clearing house exchanges, proving the postings made by the bookkeeper

and balancing daily his work, multiplying interest and discount, daily, monthly and yearly statements and in various other ways.

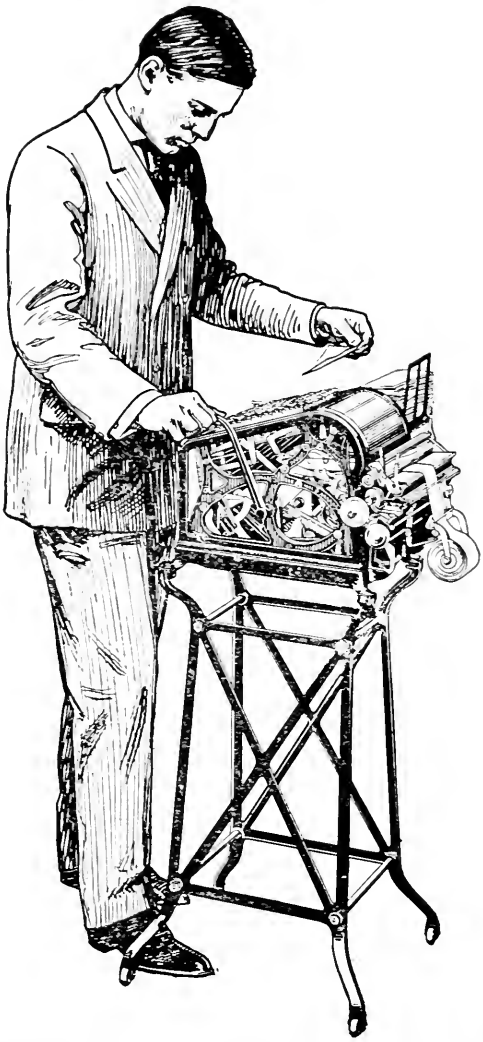
In the manufacturing concerns, the adding machine is invaluable. It enables the bookkeeper to prove daily the correctness of every entry made in his books by what is known as the "Proof of Posting System." He can then prove the addition of his ledger by the use of the statement machine which will make out monthly statements, putting down the charges and credits and extending the balance by means of subtraction. This machine is also equipped, when desired, with letters so that the operator is able to put down an abbreviation of the month and such words as Debit, Credit, Balance, etc. When all the entries in the ledger have been proven, the addition and extension checked, the trial balance then is really a mere form. The trial balance of to-day is merely a proof, made monthly, of the bookkeeper's work, and is not used for statistical purposes, as the data it gives is sufficient for such, therefore if the work is proven and balanced daily, the trial balance is then rendered very simple. The time for making up monthly statements and taking off the trial balance falls right at the end of the month and without the assistance of the adding machine the bookkeeper is badly snowed under in his work for a period of time.

The machine is also used for recapitulating sales, both by salesmen and by the department, used on pay-roll work and very extensively in cost accounting, rendering this particular work, which is of vast importance, very simple. By a system used in connection with the adding machine the cash book can be practically done away with, so far as the entering of the daily receipts is concerned, and the purchase ledger can be entirely dispensed with.

In a jobbing house the machine is used in practically the same way as by the manufacturer, except that the jobber has a greater amount of work in the recapitulation of sales, as is also the case in retail concerns and department stores, and in the latter all of the numerous sales made are audited very quickly on the adding machine.

In the railroad and insurance fields, the use of the adding machine is so extensive that the Burroughs Company has established departments of railroads and insurance. The work of these departments being devising systems for applying the machine to the

various uses of these concerns. Special machines are constructed for this work that will add and list, or list and not add, from one to four columns of figures at a time, and as practically all of the accounting done by these companies is of a statistical nature, the adding machine will eventually be so applied that it will handle nearly all of this work.



L. E. Spalding, of St. Louis, champion adding machine operator. Mr. Spalding holds the world's record of 500 miscellaneous bank checks correctly listed and added on the Burroughs in 6 minutes, 18 seconds.

In the leaf tobacco business, which has not been mentioned, invoices are used on which is shown the number of the case, the gross weight and tare of same and actual weight of contents. These four columns can be listed at one operation on a machine especially constructed for this work, and when the total is taken the gross tare and actual weights are all added at one operation.

When this invoice is made in duplicate by the use of a carbon sheet, the duplicates can be retained in loose-leaf binders as a sales book. This particular use is also applicable in oil, cotton and coal businesses, special Burroughs machines being so constructed as to fit their particular requirements.

In gas and electric light companies, the entire ledger can be made out on the adding machine, for most of these concerns handle their accounts by numbers instead of names, so the ledger sheet may be inserted in the machine and filled out complete. In the gas company's business the account number, the number of cubic feet for both lighting and fuel gas and the earnings are listed. Receipts are also handled by these companies on the adding machine, putting down the account number, the amount of discount and amount of cash received. With the electric lighting companies the use is just the same, instead, however, of listing feet, they list kilo-watt hours.

The United States Government, at the present time uses in the vicinity of five hundred machines, these being distributed in practically every department of the service.

Quite a number of adding machines have been sold to private individuals to be used in their residences for handling the accounting necessary therein, and to contractors and constructors, who use the machine for figuring estimates on jobs and then handling the cost accounting of their contracts.

The foregoing applications of the adding machine give some idea of the vast number of uses to which it has been applied. The possibilities and applications of the machine seem unlimited and the business is practically in its infancy.

The Burroughs Adding Machine Company is at present manufacturing fifty-eight different styles of adding and listing machines, and in order to better care for its ever increasing business has established offices in every city of importance in the United States, and now has representatives in practically every country on earth.

In the course of this lecture a number of slides were used, showing the various parts of the Burroughs machine and the course of the machine in its progress through the Burroughs factory.

One of the views showed the Small Parts Inspection Department, where every part entering into the construction of the ma-

chine is tested by some special instrument devised to absolutely determine the acuracy of the part.

Another showed the Assembling Department, where all these parts are brought for building up into the various sections of the machine. Then there was the Erecting Department, showing the various sections being built into a complete machine.

Following this comes the Inspection Departments, where the machines go after leaving the hands of the erectors. The inspection of the machine is very thorough. The first inspector is not limited to the amount of time he puts into the inspection of any machine. It does not leave his hands until he is satisfied, and then it passes to one of the men who are known as "Second Inspectors," who carefully examine every part of the machine for perfect workmanship, material and erection. The machine then goes to the final inspectors, who are responsible for the perfection of the machine. They test the machine in every conceivable way, and take off record slips showing the work. The machine then goes to the shipping room.

Another view showed the Special Machine Department, where all Burroughs machines having special features are assembled and tested by special inspectors.

There were a number of views of the office departments, including the Accounting Department, General Offices, Stenographic Department, Business Systems Department, etc. The latter is a most important department of the Burroughs work, and is devoted to investigating the uses for the machine in all lines of business and developing ways in which the usefulness of the machine may be enlarged.

PRECIOUS METALS IN WASHINGTON.

The mines of Washington reported to the statisticians of the United States Geological Survey an output of only $221,648 in gold in 1906, a decrease of $183,430 as compared with the production of 1905. The Republic district, in Terry County; the Pierre Lake district, in Stevens County, and the Mount Baker district, in Whitman County, divide the production. Silicious ores predominate, the placer output being about $20,000.

The silver production of the State in 1906 was insignificant, amounting to only 45,878 ounces.

Statistics of the production of the precious metals in the United States in 1906, prepared by Waldemar Lindgren, geologist, are published by the United States Geological Survey in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is now ready for distribution.

In Memoriam.

WILLIAM DANA EWART.

The death at Rome, Italy, on Sunday, May 3rd, of WILLIAM DANA EWART, will be noted with more than ordinary regret by those whom his genial disposition had made his friends and by the many others to whom his most prominent invention has made his name familiar. Mr. Ewart was born in Ohio about fifty-six

years ago and at a comparative early age gave evidence of an inventive mind and rare mechanical ability. He was the inventor of the malleable-iron detachable drive chain, first known under his name, and in later years as link-belt, which has formed an important part of agriculture and other duplicate machinery, and has, to possibly a greater extent than any other single invention, helped the wonderful progress in the development of elevating and conveying machinery during the past thirty years. This

drive chain has been continuously manufactured by the Ewart Manufacturing Company and exploited by the Link-Belt Machinery and Link-Belt Engineering Companies, till in 1906 all three Companies were consolidated into the Link-Belt Company, a corporation in which he was largely interested and whose fortunes are still largely directed by his former associates. Mr. Ewart, whose abilities brought their proper reward, was not only an inventor, but a man of executive capacity, possessing a rare gift for harmonizing differences and securing cóoperation. His health becoming impaired, he retired in his early prime from the activities of business and sought renewal of physical strength under more favorable climatic conditions abroad. O. N.

PUMICE IN THE UNITED STATES.

The production of pumice in the United States in 1906 amounted to 12,200 tons, valued at $16,750, as against 1832 tons, valued at $5,540, in 1905, an increase of 10,368 tons in quantity and of $11,210 in value. This large increase came from Nebraska, from deposits near Orleans, Harlan County, and Ingham, Lincoln County, which are being extensively worked. This Nebraska pumice is chiefly a volcanic ash or powdered pumice, and is used in the manufacture of scouring and cleaning preparations.

Although deposits of pumice are found at several localities in the United States, only those most favorably located as regards mining and transportation facilities can be worked in competition with foreign deposits furnishing the imported material, the greater part of which comes from the island of Lapari. The value of the imports of pumice in 1906 was $111,695, as against $77,489 in 1905, an increase of $34,206.

Pumice stone is found on the beach along the east coast of New South Wales and Queensland, probably having been washed across the ocean from volcanic islands. Such pumice must be of good quality, as only the lightest would make such a trip, but it would be necessary to free it from sand which it may have picked up along the beaches before it would be of value for painters' work.

The production of pumice and other abrasives in the United States in 1906 is reported by Douglas B. Sterrett, geologist, of the United States Geological Survey, in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is now ready for distribution by the Survey.

The value and tonnage of British exports of iron and steel in the first six months of 1907 exceeded all records. The total pig iron exports were 1,061,275 tons, which compare with 706,466 tons in 1906 and 449,760 tons in 1905 (six months only), and of these quantities the United States took 329,552 tons in 1907, against 114,374 tons in 1906, and 81,445 tons in 1905.

Section of Photography and Microscopy.

(Stated meeting held Thursday, March 12, 1908.)

Photographing Water in Motion.

By J. W. Ridpath.

Among the many charming bits of landscape scenery found almost everywhere over the country perhaps no single class has greater charms for the eye of the photographer, or gives him more pleasure, than does the ever popular brook. Its charms have been sung by the poet and its beauty painted by the artist; it is therefore not surprising that the budding photographer should try to catch and perpetuate its beauties.

Doubtless most persons will agree that the beauty of the brook consists largely in its winding, verdure-fringed border and its clear rippling water. If the vegetation be dry and lifeless, as in spring and autumn, the brook still retains its chief charm, the sparkling water. If by the construction of a temporary dam, or other cause, the water be cut off, the scene at once loses its attractiveness. Who admires a dry brook? Rob the ravine of its water and you rob it of its chief beauty.

Many beginners in photography imagine that because the movement of water is rapid, it would be useless to attempt a picture of the sparkling ripples, wavelets, or little water-falls, so frequently found in brooks, with anything short of a rapid lens and quick-moving shutter; and they frequently complain that they are unable to take good pictures of landscapes containing water, because the lens or shutter on their camera is not sufficiently rapid to photograph water in motion.

It is to correct this mistaken notion, and encourage the beginner to try what he can do with his camera, that this short article is written. As a matter of fact, thousands of excellent land-

scape pictures are taken with the ordinary rapid rectilinear lens and low-priced shutter, even when there is considerable wind agitating the leaves and swaying the branches of trees and rippling the surface of the water. An old-time professional photographer told the writer, that even with wet plates and their slow disposition, he had taken many landscapes for the trade, especially along streams, showing bridges, and was thought to be quite successful in photographing moving water, although the time required was

Turk bridge, near Doylestown, Pa. Exposure 1 second. Negative by the author.

what we would now call excessively long. A collection of marine views, which show the ocean in its different moods, from a rippled surface to waves breaking over the deck, were all taken by an officer of a large ocean steamship, with a Waterbury lens and a sliding shutter that was anything but rapid; and these pictures, wherever shown, were always admired.

The reasons why a liberal exposure frequently yields natural-looking water pictures, may be better understood if we remember that the average eye is incapable of forming a distinct impression of an object instantaneously. It requires a fraction of a second

to do so. By careful training the eye's speed may be somewhat increased. Robert Houdon claimed to have trained his eye to a point of time and accuracy of observation much beyond its natural capabilities. It is said that a positive image, strong and sharply marked, may be made on the retina, by a good light, in one-third of a second; and yet this does not hold true in all cases, because eyes differ. One may require nearly half a second, while another may have a clear perception in much less time, possibly one-tenth of a second. Again, an impression once made, may last on the retina as much as one-thirtieth of a second. Therefore it appears that the position of the moving object, as seen by the eye, is not its real position at that point of time, but rather the position it occupied a fraction of a second before. Again, the field of distinct vision is extremely limited; at the same moment we see clearly only a very small portion of the visual field; in reading a book the eye moves along the lines, clearly and sharply seeing only a small portion at once. By careful training this faculty may be greatly increased. Houdon, the noted French magician, by persistent practice, became able to walk past a show window, occupying perhaps two seconds of time, and then name to his son the many articles displayed in the window.

The rapid lens and quick-moving shutter have revolutionized our ideas of the movements of birds flying and animals running, and corrected many long-standing errors; but a rapid lens is not necessarily a universal lens.

In photographing a rapidly moving object, we may wish to portray what actually took place, although it may differ materially from what the eye saw; in fact the movement may have been too rapid for the eye to see it. The movement of water is very different from the movement of birds, animals, or other objects of definite shape. In photographing a rapidly-moving bullet, falling shot, a trotting horse or flying bird, we expect to show the definite shape of the moving object, rather than the movement of the object; that is, we show a bird with outstretched wings, apparently suspended in mid-air, rather than the moving of either the bird or its wings in the air. In the case of water, the individual particles are not visible, as in falling shot, therefore we show the shape of the general mass or small aggregations of the mass, and by their shape or position obtain the idea of motion. While a very short exposure may, and will, give the wave formation, sharply

defining every ripple upon the surface of the water, the resulting photograph will lack the softness of the scene as observed by the eye; and except in the matter of outline or shape, will probably lack the semblance of movement, which gave to the scene its principal charm, and to preserve which, the plate was exposed. It is true that an exposure of 1/1000 of a second would show the water of a cascade, but the resulting picture would probably resemble suspended motion more nearly than moving water.

Experience appears to show that the slight blurring caused by a

Little dam at Ogontz, Pa. Exposure 1-25 second. Negative by the author.

slow shutter, instead of detracting from the appearance of movement in water, rather enhances the idea of motion.

In photographing a landscape, with or without water in the view, we usually wish to depict the scene as we saw it, preserving that charm which appealed to us at the time; therefore the desired picture should be a representation of what the eye actually saw, rather than the details of a movement too rapid for the eye to perceive or form a clear conception of. In the opinion of the writer this effect can readily be obtained at a moderate speed, say

1/10th to 1/25th of a second, under ordinary conditions, with a good rapid rectilinear lens. We should also recognize the fact that the lens, unlike the eye, sees the whole visual field at once, and the exposure should be sufficient to show the trees and other surrounding vegetation as well as the flowing water, otherwise the short exposure for water, would give underexposure for the trees and grass.

While the writer would recommend the purchase of as good a lens as your purse can readily afford, he would advise the amateur that extreme rapidity is rarely needed in landscape work; and a good lens with shutter set at moderate speed will usually yield satisfactory work.

The paper was illustrated by thirty-one photographic slides, as follows:

1/100″—Dam in Bethlehem.
1/75 ″—Cruiser Brooklyn.
1/75 ″—Battleship Texas.
1/60 ″—Sunset.
1/50 ″—Cruiser Fulton.
1/50 ″—Breakers.
1/40 ″—Iron bridge—Bethlehem.
1/40 ″—Lighter and Tug.
1/25 ″—Ogontz Dam.
1/25 ″—Stone Bridge.
1/25 ″—Schooner.
1/25 ″—Bathers.
1/25 ″—Rustic Bridge.
1/25 ″—Breakers.
1/25 ″—Little Dam at Ogontz.
1/25 ″—Tacony Creek.
1/25 ″—Willows.
1/25 ″—Foot-bridge.
1/25 ″—Wanamaker's Lake.
1/25 ″—Sloop.
1/25 ″—Tree and Race.
1/25 ″—Schooner.
1/25 ″—Wave.
1/15 ″—Darby Creek.
1/10 ″—Dam at Rocks.
1/10 ″—Quarantine Boat.
1/5 ″—Upper Falls—Childs' Park
1/2 ″—Bushkill Falls.
1/2 ″—Liberty Falls.
1 ″—Turk Bridge.
90 ″—Valley Green Bridge.

ANNUAL REPORT OF THE DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.

The twenty-eighth annual report of the United States Geological Survey, covering the fiscal year ended June 30, 1907, just published, records some notable events in the history of that organization. The retirement of Director Walcott to assume the secretaryship of the Smithsonian Institution was distinctly the most important of these events. The new Director, George Otis Smith, in this, his first report, briefly outlines the changes made under his predecessor. Among these changes he mentions the raising of the standard of the topographic maps, with the representation thereon of land subdivision lines, and the extension of exact leveling and primary triangulation; the placing of the entire topographic and geologic force within the classified serivce; the obtaining of authority from Congress to issue in advance of the printed volume the separate chapters of the annual report on mineral resources of the United States; the enlargement of the Survey's work in hydrography, mineral resources, and geology; and the provision for reconnaissance surveys of regions of economic importance.

The growth of the Survey during the thirteen years of Mr. Walcott's administration is shown by the increase in the extent and the scope of its operations. The appropriations for the last fiscal year amounted to more than four times the total of those made thirteen years ago, and there was, of course, a corresponding increase in the amount of field and office work performed. The development of the relations between the Geological Survey and the public within the same period is measured by a more than fourfold increase in amount of official correspondence, a nearly fourfold increase in number of printed pages in the various reports of the year, and a more than fivefold increase in copies of maps printed, while the total annual distribution of publications—books and maps—grew from less than 200,000 to nearly a million copies, the sales increasing from $2,100 to more than $18,000. The extent to which the results of the Survey's work are now utilized by the industrial world and by educational and scientific institutions furnishes the best indication of the success achieved.

The completion of the separation between the Reclamation Service and the Geological Survey and the organization, within the Survey, of a technologic branch, for testing fuels and structural materials, were also important events of the year.

The report gives detailed accounts of the year's work in topography, geology, hydrography, technology, and chemistry, and in the collection of statistics of mineral resources and mineral production of the United States. Especial note is made of surveys of coal lands, of surveys in Alaska, of work relating to water resources, and of cöoperation between the States and the National Survey.

The Survey has suffered considerable embarrassment by its success as a training school for mining geologists, having lost seven geologists during the year through their employment by mining companies at larger salaries.

The publications of the year consisted of 177 new documents, 109 new maps, and 255 reprints of maps.

(Stated meeting held Thursday, May 14, 1908.)

An Improved Microscope.

By Frank Teal.

While the optical elements of the modern high power microscope have obtained a wonderful degree of perfection, and the workmanship on the entire instrument is worthy of admiration, an observing microscopist cannot fail to note certain mechanical deficiencies affecting the manipulation in high power work.

The instrument under consideration is the product of evolution (*not* Darwinian), in which—starting from a very crude and elementary nucleus—the various features to which attention is called, were suggested, *by their need,* and added, piecemeal.

To an amateur, who is not restricted in originality of thought by consideration of conventional forms and methods—possibly through his ignorance of them—a much bolder treatment of the subject may be attempted, without the exercise of any great amount of courage.

The several improvements to which attention is called may be divided into three groups: First, focusing; second, manipulation of the slide; third, illumination.

One feature, not included in this classification, may be briefly referred to, as—though exceedingly simple in itself—it is very important in its effect. Few manipulators have escaped the harrowing experience, in focusing high power work, of bringing the objective in contact with the slide; with the result of destruction of the slide, and, possibly, injury to the costly objective! The great power of the micrometer screw, due to its fine thread, renders it impossible to detect the slight increase of resistance due to a pressure sufficient to destroy the fragile slide, while the extreme difficulty of avoiding passing the focal plane—where the working

distance is short, as it is, necessarily, in immersion work—renders it difficult, even with the greatest care, to avoid such accidents. The remedy is exceedingly simple and effective, as shown.

The working barrel, to which the focusing adjustments are attached, is made of a diameter large enough to receive the body tube, which is fitted accurately to the bore of barrel, but sufficiently free to avoid friction. A collar on the tube supports the weight of the latter, and prevents downward movement, while the tube is perfectly free to move upward, with only the resistance due to its weight. In operating, should the lens come in contact with the slide, its motion ceases, and only the barrel moves, which, of course, is harmless.

By obviating the necessity for extreme care, focusing can be done with much greater rapidity, and with absolute safety.

Focusing.—For coarse adjustment the rack and pinion leaves nothing to be desired; it is quick, simple, and efficient. In the micrometer adjustment, however, the almost universal use of the milled head on the screw renders the device deficient in the necessary delicacy of adjustment in resolving difficult objects, and it was from the experience of such difficulty that the necessity for improvement was suggested.

Like Columbus' egg, the remedy was very simple. Merely a worm-wheel on the screw, in place of the conventional milled head, and a worm shaft with milled head, at right angle to the screw.

Comparing the delicacy of adjustment of the two methods—the conventional screw is 72 threads per inch, and with milled head graduated to 100 ths., the movement can be made as fine as 72x100=1/7200 of an inch.

With worm-wheel adjustment, the screw 32 th'ds. per inch; worm 32 th'ds. per inch, and milled head on worm divided to 25 ths., we have 32x32x25=1/25,600. Or, with milled head divided to 100 ths., 1/102,400 inch.

Of course the necesary take up adjustments to both screw and worm-shaft are provided, to prevent lost motion.

Slide Adjustment.—The usual spring clips are discarded, as the form of mechanical stage used renders them superfluous. The main stage is of the revolving type, graduated to 360°. It is rotated by a bevel gear and pinion movement, and provided with a locking device to retain it in position when adjusted. The top

plate of stage is provided with a male dovetail slide placed at right angle to the column. This serves as the guide for in and out movement of the mechanical stage; and also forms the working face of the main stage. The transverse movement is by means of a dovetail slide carried by a tempered steel plate 1/100 inch thick, having a central opening of a size to prevent covering the stage aperture at any point of adjustment. An internal dovetail forms the slide carrier. It is made wide enough to contain a flat, bow-shaped spring, which is set at an angle corresponding with the opposed dovetail. The slides are simply slipped into place, and are held by the spring firmly against the bottom plate, and the side of dovetail. Adjustment scales, graduated to 1/100 inch, are provided for both movements. The in and out movement is by spiral rack and pinion; and the transverse movement by quick thread screw. The pinion and screw shafts are carried out to convenient distance beyond the stage, and are provided with milled heads. Being side by side, the manipulation of the slide is exceptionally convenient. Owing to the extreme thinness of the mechanical stage, the sub-stage condenser (Abbe) may be brought into immersion contact with the slide, even with the stage iris is closed to smallest aperture.

ILLUMINATION.—A very simple and efficient device is provided by which the column may be rotated independently of the base. The motion is perfectly smooth and easy, and yet there is sufficient friction to prevent accidental movement. The value of this adjustment can only be realized from experience in its use. Frequently a mere touch will resolve an object after much vexatious effort with all other adjustments.

While the sub-stage—i. e., the Abbe condenser, with its various adjustments and accessories—is of entirely original design, there is no thought of its showing any superiority over existing types.

One of the most important points in connection with illumination seems to have been completely ignored by makers of these instruments, in their failure to provide mechanical means for mirror adjustment. The crude method of tilting and pulling the mirror this way and that, by grasping it with finger and thumb, is but little calculated for movements which, really, require extreme delicacy. The advantages of such adjustment cannot be fully realized without experience of how infinitesimal a movement can

produce the desired effect, which could otherwise be only laboriously obtained.

The mirror bar is capable of swinging to about 45° either side for extreme oblique illumination; and, by means of a parallel rod and binding screw, can be rigidly locked in any adjusted position. The bar is bored throughout its length to receive a post, to which the yoke of mirror frame is attached. The post is held in any desired position by means of a binding screw, and admits of up and down, and radial adjustments of the mirror. The mirror yoke is attached to the post by a trunnion provided with a worm wheel. and is actuated by a worm shaft with milled head. The trunnions of mirror frame are also provided with worm wheel adjustment, at right angle to movement of the yoke. Neither of these devices interferes with manipulating the mirror in the ordinary manner, but the use of them firmly locks it in the adjusted position.

AUTOMATIC IRIS SHUTTER.

The distinctive feature of this shutter is the adaptation of the iris diaphragm principle to the functions performed by other types of shutters, with the object of obtaining a more symmetrical action of light in making exposures.

The action of the iris—whether used as a shutter or a stop—is, necessarily, the same; it effects an equalization of focus in either case, without disturbing the degree of uniformity of illumination due to the quality of the lens.

The form of iris used for a diaphragm or stop, requiring a large amount of applied motion to effect the two extremes of adjustment, is, obviously, inapplicable to the shutter.

In case of the latter, the necessity for extremely rapid movement in opening and closing for instantaneous exposures, limits the amount of applied motion to a relatively short travel, and therefore, requires a construction of the iris, the reverse of that used as a stop. Also, as it is manfestly impossible to completely close this aperture, a supplementary leaf, having an independent movement, is necessary for completing the closure, to render it light proof.

To obtain the required rapidity, and to avoid shock at the change of motion from opening to closing, a continuous applied motion is, practically, a necessity; and, in conjunction with the

other elements of the actuating device, the toggle appears to afford the most desirable form of mechanical movement.

This toggle is centrally connected to the piston rod of a pneumatic cylinder, and is guided, for the entire stroke, in the central position; thus causing equal end motion, outwardly, to the two links. The outer ends of the latter are connected to a pair of rockers, or bell-cranks, which are, in turn, adjustably connected to the operating rings of the iris. As these rings are caused to move in opposite directions, the amount of applied motion required is but one half of what would be necessary if one of them were stationary; and as a resultant of this arrangement, the speed of the shutter is doubled.

As previously stated, a single impulse of the pneumatic piston will effect both the opening and closing motions of the shutter; and by simply arresting the movement at half stroke, at which point the toggle is fully expanded, the shutter will remain open until closed by a second impulse of the piston. By this means there is great latitude possible in making time exposures—say from a quarter second to any interval desired.

It follows, from this arrangement, that, in order to avoid the necessity for setting the shutter after making an exposure, a double acting pneumatic cylinder is required, so as to make the return stroke of piston effective, in the same manner as the outward stroke.

The term "automatic," as applied to this shutter, is descriptive, in that, in operating it, for either instantaneous or time exposures, it is only necessary to press the pneumatic bulb, regardless of the position of the piston or its connections. To effect the reversal of piston movement, a very simple air-impelled valve is supplied to the cylinder, the action of which is to cause admission and exhaust at the two ends, alternately, in the same manner as the slide valve of a steam engine. The valve is unconnected with any of the moving parts—receiving its motion from the action of the air at each pressure of the bulb—and it is impossible to give an impulse to the piston without causing a coincident reversal of the valve. The entire device has proved entirely satisfactory, after having been in use for about six years.

EXPORTS OF FOREST PRODUCTS.

Uncle Sam's exports of forest products have shown higher and higher values during the last five or six years. This has been the case, although reports show that there has not been a corresponding increase in volume. For instance, the quantity of sawed timber exported from this country has increased less than twelve per cent. in the last four years, while the price has increased over fifty per cent. Again, the amount of rosin exported has increased but little, while the price has more than doubled.

From 1903 to 1906 the value of staves showed very little increase, but in the year 1907 there was a decrease in the number exported of about ten per cent. together with an increase in the price of about twenty per cent. This last would seem to indicate a recognition of the fact that the supply of the highest grades of white oak is rapidly diminishing. The staves exported are almost exclusively of the highest grades of white oak, and form about one-fifth of the annual production of white oak staves in the United States. As might be supposed, a large part—eighty per cent—of the staves went to Europe, forty per cent. to France. The export trade makes a heavy drain on the supply of white oak.

Boards, deals, planks, and sawed timber made up fifty per cent. of the total value of forest product exports. Rosin ranks next, with nearly ten per cent. of the total value of these exports. Spirits of turpentine follows with about ten per cent. Four-fifths of the rosin and turpentine go to Europe.

The number of shingles exported has decreased fairly regularly since 1903. In 1907 there were shipped less than half the number that were exported four years before. More than fifty per cent. of these shingles go to Mexico, while less than ten per cent. were shipped to ports outside of North America. This shows how few shingles are in demand abroad. The total exports of shingles represent less than one-fifth of one per cent. of the production of this class of material in the United States.

The amount of wood exported in the form of hewn or sawed timber and lumber was about seven per cent. of the total lumber cut in the United States in 1907. More yellow pine is exported than any other kind of timber. The order is yellow pine, Douglas fir, and redwood. Although there are no figures which bear directly on the amount of yellow pine lumber annually exported, it is estimated that at least thirteen per cent. of the yellow pine cut finds its way to other countries. Probably a third of the Douglas fir exported went to South America.

The redwood exported forms an important item. Australia and the Orient together took forty per cent. of the total and South America thirty-two per cent. The exports of redwood in 1907 were about five times what they were twelve years ago, and were larger than those of any previous year. The shipments to Australia and the Orient especially have been increasing steadily during this period. The shipments to South America of redwood, as well as a number of other forest products, has increased greatly in the past two years.

Section of Physics and Chemistry.

Formation and Preparation of Aluminum Carbide.

By M. Camille Matignon,

Translated from "Annales de Chimie et de Physique," Eighth Series. Vol. XIII, p. 276, February, 1908,

By W. J. Williams, F. I. C.

Aluminum carbine, C_3Al_4, was prepared for the first time by Moissan* by heating aluminum in a charcoal crucible in the electric furnace. This scientist has recorded the principal properties of this combination and has drawn particular attention to its gradual (slow) decomposition by water, with the production of methane.

$$C_3Al_4 + 6H_2O = 3\ CH_4 + 2\ Al_2O_3.$$

Moissan's discovery had been preceded by the investigations carried on by Mallet and Franck, with the object of combining aluminum with carbon.

Mallet† had heated the metal in a charcoal crucible lined with lamp-black, without effecting the slightest combination. The operation was conducted in a Deville furnace, in which a temperature above 1700° can be attained, yet the metal showed no other change than a deposit of carbon adhering to the surface. This compact carbon was the result of the reduction of the carbon monoxide, formed at the expense of the carbon di-oxide gas, passing over the plumbago crucible.

Later Franck,‡ repeating Mallet's experiment, believed he obtained small quantities of aluminum carbide by raising a mixture of powdered aluminum and lamp-black to a very high tempera-

---

*Comptes Rendus, Vol. CXIX, 1894, p. 16.

†Journal of Chem. Soc., Vol. II, 1876, p. 349.

‡Bull. Soc. Chem., Third Series, Vol. XI, 1894, p. 446.

ture. The product had not changed its appearance, but when treated with dilute hydrochloric acid it disengaged hydrogen mixed with a little acetylene. From the presence of this gas Franck concluded the production of a small quantity of carbide. This conclusion was obviously inexact, since, as Moissan showed later, aluminum carbide does not give off acetylene from contact with water. Besides, it is easy to understand the mechanism of the production of acetylene in another way. Lamp-black always contains small quantities of calcium salts, the phosphate and the sulphate, which are reduced by the excess of aluminum setting free calcium, and this metal combines immediately with carbon to form calcium carbide, which is decomposed by water with the production of acetylene.

In 1901, Berthelot* undertook to determine the heat of formation of aluminum carbide, prepared by Moissan's method. The sample used left an insoluble residue after treatment with hydrochloric acid amounting to 4.74 per cent. Further, it was difficult to attain the total combustion of the carbide in the calorimetric bomb, so that the value obtained could not be considered as determined with great precision. Nevertheless the actual heat of formation is closely approximate to the figure obtained by Berthelot after making corrections; $C_3 + Al_4 = C_3Al_4 + 244.8$ Cal.

Notwithstanding the above reservation, this is incontestably a very high figure. To make a comparison let us compare as well the heat disengaged by 1 atom of aluminum to form the carbide, the iodide and the sulphide; we obtain the following table:

C	61.2 Cal.
I	70.3 "
S	63.2 "

with numbers of the same order of magnitude.

In spite of the unsuccessful attempts of Mallet and Franck, it occurred to me, considering the great heat of formation, that the combination of the two elements could be realized, without the intervention of the high temperature of the electric furnace; at least, although *a priori* it seemed but slightly probable, that the reaction would not exceed the zone of "fritting" except at this very elevated temperature. Experience verified my foresight.

---

*Comptes Rendus, Vol. CXXXII, 1901, p. 281.

I. Aluminum carbide can be conveniently prepared by heating an intimate mixture of the two constituents in a Perrot furnace. It is well to use an excess of aluminum, which is easy to separate from the carbide produced. Experiments have been made employing the following proportions: 24 parts of carbon to 70 or 140 parts of metal. The carbon is taken in the form of lamp-black, previously calcined to remove moisture. Its intimate mixture with the powdered aluminum is insured by kneading them with spirits of turpentine. The reaction is finished after heating 20 minutes in a good Perrot furnace.

The roasted product presents the form of a well-fritted mass of a slightly olive yellow color. Under the microscope the carbide presents a crystalline appearance; if an excess of aluminum has been used, it is interspersed with small, brilliant globules. These globules can be easily removed, as Moissan has shown, by a rapid treatment with cold hydrochloric acid, or, perhaps better, by substituting a solution of potassium hydroxide for the hydrochloric acid. The carbide is attacked so slowly that decomposition is prevented.

Before making a communication* recently to the Academie des Sciences, on this subject, which I had studied in 1903, I had examined the products of the preparation and had recognized in some of them the presence of small, brilliant metallic scales, yellow, of a hexagonal shape, of almost uniform dimensions of about 0.20 mm. in diameter. The very transparent, yellow scales had the same appearance as the aluminum carbide crystallized by Moissan; hence I thought I had obtained this body in a well crystallized condition. In fact, however, these crystalline scales did not disengage any gas after being in contact with rain water for two weeks; they preserved the same appearance after two weeks' exposure to the air. It seems very probable that these scales consist of aluminum oxide colored yellow by traces of impurities.

A sample of good appearance containing aluminum was attacked by water without having the excess of aluminum previously removed. A gas was obtained which was submitted to eudiometric analysis:

Total gas	5.6 c.c.
Oxygen added	14.35 "
After the spark	8.95 "

*Comptes Rendus, Vol. CXLV, 1907, p. 676.

After absorption by KOH. 3.65 c.c.
After absorption by pyrogallic acid..... 0.00 "

This composition is deduced:

CH_4.....	96.36 cc.
H.....	3.63

The decomposition of the carbide by water is very slow, and requires several weeks; during this time the aluminum in excess, especially in the presence of aluminum hydroxide, decomposes a little of the water, setting free hydrogen. Practically the gas is almost pure methane.

With a product freed from metal in excess, the gas collected is pure methane, as was proved by volumetric analyses:

Gas analyzed.....	4.0 c.c.
Oxygen added.....	21.3 "
After the spark.....	17.05 "
After absorption by KOH.....	13.05 "
After absorption by pyrogallic acid.	0.03 "
Contraction	8.25 "
CO_2	4.00 "
Oxygen absorbed.....	8.28 "

Theoretically, pure methane would give:

Contraction	8.00 c.c.
CO_2	4.00 "
Oxygen absorbed.....	8.00 "

Not only does aluminum carbide give pure methane, but also yields almost the theoretical quantity of gas.

0.2323 gram of the purified product disengaged successively in contact with water 42.5 cc. of gas collected at 17.5°, then 69.5cc. measured at 23° under atmospheric pressure. The total volume of gas reduced to 0° and 760 mm. was found equal to 103.6 cc. instead of 108.4 cc. according to theory, being a yield of 95.6 per cent.

6.3 cc. obtained from the first portion were analysed:

Gas	5.5 c.c.
Oxygen added.....	17.85 "
After the spark.....	12.45 "
After absorption by KOH.....	7.05 "
After absorption by pyrogallic acid.	0.05 "

Contraction	10.9	c.c.
CO_2	5.4	"
Oxygen absorbed	10.9	"

Pure methane would have given:

CO_2	5.45	c.c.
Contraction	10.90	"
Oxygen absorbed	10.90	"

In another operation 0.2775 gram of carbide gave, after being attacked by water for several months, a total disengagement of 125 cc. instead of the theoretical 129.5 cc., a yield of 96.6 per cent.

II. If iodine and sulphur are intimately mixed with powdered aluminum, they combine rapidly as soon as combination has been artificially provoked at one point of the mixture. It was natural to try if the re-action of carbon on aluminum, which disengages a quantity of heat of the same order of magnitude, would propagate itself if it should be started with a primer as in Goldschmidt's method.

Experience showed that to obtain this result it was necessary to use an excess of aluminum. An intimate mixture of 24 parts of carbon to 140 parts of aluminum re-acted with the formation of the carbide when the priming powder (binoxide of barium and aluminum) was ignited on its surface, the re-action continued to the bottom of the crucible; it was complete. In fact, a part of the aluminum in excess combines with the oxygen or with the nitrogen of the atmosphere and consequently produces a complementary heat which facilitates the synthesis of the carbide.

The re-action sets free pure methane, or methane mixed with hydrogen, according as the product has, or has not, been purified.

Here are the results of an analysis of methane obtained by decomposition of a product prepared without exterior heat:

Gas analyzed	6.0	c.c.
Oxygen added	17.5	"
After the spark	12.1	"
After absorption by KOH	6.45	"
After absorption by pyrogallic acid	0.35	"
Contraction	11.40	"
CO_2	5.65	"
Oxygen absorbed	11.40	"

Methane gives:

Contraction	11.30	c.c.
CO_2	5.65	"
Oxygen absorbed	11.30	"

III. It is evident from the preceding results that carbon and aluminum will react when a mixture of them is heated with the aid of the oxy-acteylene blowpipe. Practically, the roasted product obtained after some minutes heating re-acts slowly with water, giving off almost pure methane.

A single analysis was made and gave the following results:

Gas analyzed	3.8	c.c.
Oxygen added	10.0	"
After the spark	6.3	"
After abs rption by KOH	2.7	"
After absorption by pyrogallic acid	0.2	"
Contraction	7.5	"
CO_2	3.6	"

Methane gas should give a contraction of 7.2 with a volume of 3.6 of carbon dioxide gas.

IV. Aluminum carbide can also be prepared by compelling the chlorides of carbon to act on the metal. *A priori* the success of the method does not appear doubtful, if the disengagement of heat corresponding to the re-action is considered. With hexachloro-benzene, for example, the re-action is

$$10\ Al + C_6Cl_6 = 2\ AlCl_3 + 2\ C_3Al_4 + 727.6\ Cal.$$

Besides the volatility of the aluminum chloride permits the separation of the two products of the re-action, and the pure carbide can be obtained.

Powdered aluminum, previously freed from foreign matters which render it impure, is mixed with the theoretical proportions of Julin's chloride, C_6Cl_6, and the whole is heated in a sealed tube at a temperature of 225° C. Under these conditions, the reaction, which is very exothermic, is often very violent, and the sealed tube frequently breaks if there is any notable quantity of matter. To avoid this inconvenience it is necessary to introduce only a small quantity of matter and to spread it all over the length of the tube held in a horizontal position during the heating. In this operation, carried out in a closed vessel, I have used benzene per-

chloride, which is less volatile than the other carbon chlorides, in order to decrease the pressure in the tube.

When the reaction is incomplete the carbon chloride in excess and the aluminum chloride can be easily removed by a current of hydrogen gas. A rapid washing with water carries off the aluminum chloride.

The burned product of an unfinished reaction has decomposed water, forming methane and hydrogen, finely divided aluminum reacting easily on the latter in presence of aluminum chloride, as M. Ditte has shown.*

In an earlier analysis, made before the isolation of the carbide, a gaseous mixture was obtained consisting of 44.7% of methane and 55.3 % of hydrogen;

Gas analyzed	6.02	c.c.
Oxygen added	13.37	"
After the spark	8.95	"
After absorption by KOH	6.25	"
After absorption by pyrogallic acid	0.0	"
Contraction	10.44	"
CO_2	2.70	"
Oxygen absorbed	7.12	"

The mixture indicated above would have given:

Contraction	10.41	c.c.
CO_2	2.70	"
Oxygen absorbed	7.07	"

The same product rapidly washed with water to remove the aluminium chloride yielded much less hydrogen:

Gas analyzed	5.2	c.c.
Oxygen added	12.6	"
After the spark	7.6	"
After absorption by KOH	2.9	"
After absorption by pyrogallic acid	0.0	"
Contraction	10.2	"
CO_2	4.7	"
Oxygen absorbed	9.7	"

The gaseous mixture analysed then contained 90.4% methane and 9.6% hydrogen. Theoretically, such a mixture would yield:

*Ditte: Researches on the properties of aluminum and its applications. Paris. 1900.

Contraction	10.15 c.c.
CO_2	4.70 "
Oxygen absorbed	9.65 "

Finally, the same mixture, after removing the metal in excess by a rapid treatment with cold alkaline solutions, gave pure methane.

Gas analyzed	5.14 c.c.
Oxygen added	14.6 "
After the spark	9.50 "
After absorption by KOH	4.46 "
After absorption by pyrogallic acid	0.05 "
Contraction	10.24 "
CO_2	5.04 "
Oxygen absorbed	10.18 "

I have said that the action of the metal on Julin's chloride was difficult to effect, and, at the same time, avoid rupturing the sealed tube. If the initial mixture is heated in a test-tube, the reaction is extremely violent. The mixture can also be placed in a crucible and the combination be induced in one spot by the help of an appropriate primer, ignited by the aid of a magnesium wire; it causes a large, luminous flame with copious fumes of aluminum chloride; and the greater part of the matter is ejected; in every case an extremely light substance, containing some metallic carbide remains at the bottom of the crucible.

Aluminum carbide is also produced when the metal is heated in a current of the votalilised vapor of a carbon chloride, e.g. the tetra-chloride.

V. In the preparation of carbide by the synthetical method, some aluminum nitride is always formed in the portions of the mass near the surface; in some preparations, imperfectly conducted, the central part of the crucible also contained nitride. In that case the decomposition of the carbide by water gives ammonia as well as methane, but this ammonia has a very characteristic odor of amine. It may be that in the presence of nitrogen, the carbide and the aluminum are capable of forming a carbamine decomposable by water with the production of amines.

M. Fichter* has, however, recently shown that aluminum carbide, heated in a current of nitrogen, yields a nitride, while carbon is set free. The re-action would be:

---

*Zeit. Anorg. Chem., Vol. LIV, 1907, p. 322.

$\frac{1}{2}C_3Al_4$ (sol.) $+ N_2$ (gas) $= 2\,Al\,N$ (sol.) $+ \frac{3}{2}\,C$ (sol.) -67.7 Cal., which would be endothermic, if the heat of formation attained by the nitride, as determined by M. Fichter, is taken into account.

This reaction constitutes a system in which only solids and a gas are included, but as I have shown,* similar systems can only be realized in the sense of the transformation indicated by

$$\frac{1}{2}\,C_3Al_4 + N_2 \rightrightarrows 2\,Al\,N + \frac{3}{2}\,C.$$

when the heat of the re-action is positive and greater than a certain quantity variable with the nature of the gas. It must be concluded then either that the re-action is incorrect or that the thermic valuation corresponding to it contains a large error. It is a point which should be more closely examined.

VI. The preparation of Aluminum carbide, starting from the metal and carbon-chlorides, can be generalized whenever the metal has sufficient affinity for chlorine. In every case the product of the re-action will be a mixture of the metallic carbide and chloride, usually easy to separate by using organic solvents of the chloride which have no chemical action on the carbide.

In fact, if the heat of formation of the chlorides is examined, which gives an approximate measure of the affinity of the metals for chlorine, the following table is obtained:

$2\,K\,Cl$	205.6 Cal.
$Ca\,Cl_2$	190.3 "
$\frac{2}{3}\,La\,Cl_3$	175.3 "
$Mg\,Cl_2$	151.8 "
$\frac{2}{3}\,Al\,Cl_3$	108. "
$Zn\,Cl_2$	97.4 "
$Cd\,Cl_2$	93.7 "
$Fe\,Cl_2$	82.2 "
$Sn\,Cl_2$	80.9 "
$\frac{1}{2}\,Si\,Cl_4$	64.0 "
$\frac{2}{3}\,Bo\,Cl_3$	59.4 "
$\frac{1}{2}\,C\,Cl_4$	37.9 "
$\frac{1}{3}\,C_6\,Cl_6$	28.4 "

which enables us to foresee the decomposition of the carbon-chlorides by a large number of metals, with the simultaneous production of carbides. This production of carbide at low temperature

*See a memoir on this subject entitled "Conditions of the Possibility of Certain Reactions Forming Monovariant Systems," which will soon appear in the "Annales."

should undoubtedly permit of the production of new, unstable bodies at the temperature of the electric furnace. I intend to try this new method and later to divulge the results.

Hence it is evident that the metals in the first terms of the above list should give actually explosive re-actions with the carbon chlorides. For example, calcium will disengage with benzene perchloride an enormous quantity of heat, as

$$2\ Ca + \tfrac{1}{3}C_6\,Cl_6 = Ca\,C_2 + Ca\,Cl_2 + 168.2\ Cal.$$

If intimate mixtures are made of finely divided calcium or magnesium, with Julin's chloride, hexa-chloro-carbon, C_6Cl_6, these mixtures can be ignited by a magnesium wire and give an explosion or a shower of sparks. There only remains at the bottom of the crucible a small quantity of matter, which sets free acetylene on contact with water. Therefore, in the two cases there are formed calcium carbide and magnesium carbide, the latter mostly decomposed. It therefore becomes necessary to regulate these very violent reactions by slowly passing the vapors of a carbon chloride over the heated metal at the lowest possible temperature.

VII. It may be asked if the elements arranged in the same group as aluminum would not, like this last, combine easily with carbon. Carbon boride appears to be formed, so far as can be judged by its properties, with a very great disengagement of heat; but, on the other hand, its two constituents, boron and carbon, are bodies of great inertia in most of their reactions; nevertheless they are suitable for making the attempt of their synthesis by simply heating in a Perrot furnace. A certain number of rare metals belong to the same group; it would not be surprising if some of them should form carbides directly; I have, however, tried, unsuccessfully, to combine neodymium and carbon; with lanthanum there would be better chances for a successful issue.

Summarising, it is possible to obtain aluminum carbide under the following conditions:

1st. By heating an intimate mixture of the two elements in a Perrot furnace.

2nd. By inducting the combination of the metalloid and the metal in a mixture containing an excess of aluminum by means of an ignition cartridge.

3rd. By decomposing carbon chloride by aluminum.

This last reaction may be generalised.

(Stated meeting held Thursday, March 5, 1908.)

The Transformations of the Elements.

By Harry F. Keller, Member of the Institute.

The report some time ago that a famous chemist has succeeded in producing certain elements of low atomic weight from other elements of high atomic weight has aroused a widespread and profound interest in the old question, "Are the substances known as the chemical elements the ultimate constituents of matter; are they really incapable of resolution into still simpler substances?"

While there can be no doubt of the high scientific character and accuracy of the work of such investigators as Profs. Ramsay and Rutherford, it would seem that the sensational accounts of the results of their work that have appeared in newspapers and popular magazines have led to extravagant, if not altogether erroneous impressions as to what has actually been accomplished. As in many previous instances the modest and cautious statements of the discoverers have been distorted and exaggerated into the most absurd claims. Thus we hear of "the dream of the alchemists realized," and of the transmutation of the metals, the base into the precious, as a matter beyond dispute. To be sure, the market values of gold and silver have not suffered the slightest depreciation, nor do those who have any acquaintance with the advances in physical science entertain such wild fancies. It has seemed to me, however, that it might not be amiss at this time, even before an audience trained in chemical reasoning, to attempt a brief, albeit imperfect, review of the experimental evidence that has been gathered on what may be termed the atomic transformations of matter.

I would have it understood at the outset that it is not my

purpose either to consider exhaustively the very extensive literature on the subject, or to attempt drawing any new conclusions from recearches of which only the first beginnings have been recorded by the master minds who are conducting them, of researches which, doubtless, will bring to light a multitude of facts that will guide us to a clearer understanding of the constitution of matter.

Let us begin, then, by inquiring as to the exact meaning of the word element, as it is now understood by chemists. Concisely stated, we regard as an element a substance out of which two or more essentially different substances have not been obtained, or as a substance which, though it may pass through numerous transformations, can always be recovered in its original form and in undiminished quantity from the compounds into which it enters. Take, for example, mercury. No one has yet succeeded in splitting up this substance into several distinct kinds of matter; and when we combine it with oxygen, with chlorine, or with sulphur, we can still extract the mercury as well as the other elements from the compound so produced, and the sum of their weights will be exactly equal in the weight of the compound. It is to the great philosopher, Robert Boyle, that we owe this conception. His famous work, the Sceptical Chymist, published in 1680, sounded the death knell to the Aristotelian doctrine of the Four Elements, earth, water, fire, and air, and of the Tria Prima—salt, sulphur and mercury—of the alchemists.

Boyle's arguments were based on observation and experiment, and his views of the "True Principles of Things" have been universally accepted for more than two centuries: our test of an element in its absolute homogeneity.

Up to the present day about eighty substances have been discovered which seemed to possess this characteristic. That it is by no means an easy matter to demonstrate this for an hitherto unknown substance, is abundantly borne out by the story of the discovery of our elements. New elements have been frequently announced, only to be placed on the now very long list of defunct ones. Time and again the supposed new element has turned out to be one already recognized, but masquerading under a new garb or contaminated with impurities. In spite of all the splendid analytical work done by American chemists, the discovery of a new element is an honor that we still have to wish for our country.

From time to time it has been claimed that certain of the recognized elements could be resolved into simpler substances; but when the supposed cleavage products were more carefully examined as to their chemical reactions, atomic weights, spectra, etc., it was invariably found that some blunder had been committed.

Nevertheless, the belief that our elements can be resolved into a primordial substance has survived even among chemists, and it would be quite an interesting, if laborious, undertaking to collect from the writings of scientists, philosophers and poets, the various expressions of opinion on this point, from Boyle down to the present day. A number of such quotations were given by Prof. Crookes in his interesting lecture on "The Genesis of the Elements." As a rule, however, they were visions that sprang from metaphysical speculations; in many cases, too, they were merely the survival of the alchemistic doctrine of the transmutability of metals.

Thus we read in the Sceptical Chymist, "men will never be able to explain the phenomena of nature, while they endeavor to deduce them only from the presence and proportions of such and such ingredients, and consider such ingredients or elements as bodies in a state of rest; whereas indeed the greatest part of the affections of matter, and consequently the phenomena of nature, seem to depend upon the motion and contrivance of the small parts of bodies."

And Faraday, in a course of lectures on the metals, held in 1818, made this remarkable statement, "to decompose the metals, then to reform them, to change them from one to another, and to realize the once absurd notion of transmutation, are the problems now given the chemist for solution."

I have selected these passages not because I consider them as revealing any special prophetic power on the part of their authors, but rather on account of the new meaning we can read into them in the light of the recent developments in physical science. They might indeed have been suggested by the discoveries of which it is my object this evening to give you an account.

This new chapter in the History of Physical Science may be said to begin with the observation of Henri Bequerel, in 1896, that phosphorescent uranium compounds, as well as the metal itself, have the property of acting upon photographic plates, even after they had for a long time been kept in a dark room. It was

further noticed that the rays emitted by these substances penetrated through opaque bodies, such as black paper, and, like the X-rays, had the power of discharging electrified bodies placed near their source. Shortly afterwards it was shown by Mme. Curie that thorium and its compounds share these remarkable properties with radium, and further that the activity of the latter is not affected by its combination with other elements. Yet, in the case of uranium *minerals,* it was observed that their activity was considerably greater than the degree calculated from their uranium content, and hence Mme. Curie concluded that this excess could only be due to the presence of some unknown substance of superior activity, and she forthwith proceeded to search for it. A ton of uranium residues was placed at her disposal by the Austrian Government for this purpose. After a long and laborious search, in which she was guided by the indications of the electroscope, Mme. Curie succeeded in separating two extremely active substances from the residue. The one first discovered was separated with the bismuth of the ore, and given the name *polonium,* in honor of Poland, Mme. Curie's native country. The second active substance, or element, was separated with barium, and as it turned out to be still more active than polonium, it received the very appropriate name *radium.* The task of separating the latter from the barium presented enormous difficulties, but was finally accomplished, the radium being obtained in the form of its chloride. Although the amount of this salt, in the pure state, was very small, Mme Curie was able to characterize the new element by a determination of its atomic weight (it is 226.18, according to recent experiments), and by an examination of its spectrum, by Demarcay. This spectrum shows several very bright lines and resembles the spectra of the alkaline earth metals, which radium also closely approaches in its analytical behavior.

The metal has not been isolated, but there is no room for doubt that if it could be reduced, it would be found strongly active. The separation from barium is based upon the fractional crystallization of the chloride or bromide. It is estimated that a ton of the pitchblende from Joachimsthal contains less than .2 gms. of radium.

Since the discovery of polonium and radium a considerable number of substances emitting similar rays have been examined, and several active elements or bodies have been extracted from

them. While special names have been given to these substances, it remains to be shown that they are true elements. The property of emitting rays, like those of uranium or radium, it termed *radioactivity,* and substances possessing this property are said to be radioactive. Among the well-characterized radioactive elements we have uranium, thorium and radium; while polonium, actinium, emanium, radiotellurium, radiolead, and ironium are strongly radioactive bodies which have not been sufficiently studied to be placed on the list of elements.

The subject of radioactivity has been very ably discussed and illustrated in a lecture before the Institute by Drs. Bradbury and Partridge. They have shown you how this remarkable property may be detected and measured by its effects on the fluorescent screen, the photographic plate and the gold-leaf electroscope. The latter affords the most delicate method and the one now exclusively employed for quantitative tests, *i. e.,* for measuring the degree of radioactivity. To this end the electroscope is charged and the substance to be tested brought on the bottom of the case of the electroscope. The air within now suffers a change known as "ionization," which manifests itself by causing the discharge of the electrified body. Assuming the degree of this ionization to be proportional to the radioactivity of the substance under examination, the relative intensity of two radioactive substances can be ascertained by observing the rate of fall of the gold leaf.

One of the most interesting properties of certain radioactive substances of radium, thorium and actinium, for example, consists in that they continuously give off a gas, or emanation. This gas is radioactive and also differs in other respects from all other gases with which we are acquainted. The emanation rapidly disintegrates and is transformed into other substances. Only one of the products has been identified with a known element: Prof. Ramsay has shown that *helium* exists among the disintegration products of radio emanation.

The importance of this observation can hardly be overestimated, for it is the first recorded instance of the transformation of one well-defined element into another. The suggestion that helium might be a cleavage product of the radioelements was first made by Rutherford and Soddy, in 1902, and it was experimentally verified in the following year, when Ramsay and Soddy procured a specimen of a pure radium bromide, made by Giesel, and

examined the gas, which was given off on dissolving this salt in water. After removing the oxygen and hydrogen, they introduced the remaining bubble into a Pluecker tube and found that it gave the characteristic D3 line of helium. A repetition of the experiment with another specimen of radium bromide afforded even more conclusive results, in that the purified gas, on being sparked in the vacuum tube, showed the entire helium spectrum.

It may be well here to recall the interesting circumstances connected with the discovery of helium. The bright yellow line of its spectrum was first observed by Janssen and Lockyer, in 1868, when these astronomers examined the chromosphere of the sun. As it did not coincide with any line in the spectra of the then known terrestrial elements, it was assumed to belong to a new element, for which Lockyer proposed the name helium. The yellow line, as well as others that were found to accompany it, was also noticed in the spectra of many stars, but it was not until 1895 that helium was discovered as a terrestrial element, and found to be a gas resembling argon. This gas has been previously extracted from cleveite, a variety of pitchblende, by Dr. Hillebrand of Washington, but remained unrecognized until it was purified and carefully studied by Ramsay, and independently by Langlet, of Upsala. Since then it has been found rather widely distributed; it is present in many minerals containing uranium and thorium, in fergusonite, in the gases of certain mineral springs, and, in traces, among the gases of the atmosphere. It is characterized by its low specific gravity (two compared with hydrogen), and by a brilliant spectrum which contains besides the yellow line a number of others in the red, green, blue and violet. Like argon, it is inert and monatomic.

When Ramsay and Soddy first published their discovery that helium is a product of the disintegration of the radium emanation, many scientists were inclined to doubt the correctness of their observations, or, at least, of their interpretation of the results. But the formation of helium from radium has since been abundantly confirmed by other investigators, and what appears to be conclusive evidence has been secured to show that the helium was not originally present, or occluded, in the radium bromide.

Thus Ramsay and Soddy collected the emanation from 60 mg of the bromide, condensed or liquefied it by means of liquid air (a process first employed by Rutherford to separate other gases from

the thorium emanation), and pumped out the gaseous admixtures. The emanation was then volatilized and transferred to a diminutive Pluecker tube. At first not the slightest indication of helium could be obtained, but after three days the brilliant yellow line appeared, and a few days later the entire spectrum of helium was distinctly visible. This left no doubt as to the source of the helium.

To show that helium gas is directly produced by the atomic transformation of radium, Curie and Dewar have made a most convincing experiment; they placed a considerable quantity of radium chloride into a quartz tube, heated the salt until it was fused, and evacuated the tube. After the emanation and other gases had thus been removed, the tube was sealed. A month later it was found by the spectroscopic test that the tube contained helium.

It is interesting to note that helium has also been obtained from actinium preparations.

An enormous amount of experimental work has been done to ascertain the exact nature and origin of the radioactive emanations, but owing to the extremely minute amount and the unstable character of these gases, their investigation has been attended with the greatest difficulties.

That they are gases may be inferred from the fact that they mix with air, and when so mixed retain their power of ionizing the air, so that the latter will discharge an electroscope. Both the emanations from thorium and radium are condensable at temperatures below 154° C. The emanations of thorium and actinium are too short-lived to be collected and measured, but the radium emanation, whose rate of decomposition is very much slower, has been obtained apparently free from other gases. And while it has not been possible to ascertain its exact density, it is estimated that the latter cannot be far from 100. We shall presently see that in all probability the emanation belongs to the helium group, or inert gases, whose atomic weights are equal to twice their densities. Ramsay has indeed thrown out the suggestion that the radium gas may have an atomic weight of 216.5, and thus fill the gap after xenon in the periodic table. The only kind of rays emitted by the radium gas are the alpha rays.

Towards chemical agents the emanations, both of thorium and radium, behave like the inert gases of the atmosphere. At a red

heat they remain unchanged when brought in contact with substances like oxide of copper, zinc dust, magnesia-lime mixture, or platinum black and oxygen. Neither are they affected when sparked with oxygen in the presence of caustic alkali. Prof. Ramsay has also found that the radium emanation has a definite spectrum, which he describes as very brilliant and as consisting of a number of well-defined lines, like the spectra of the helium family.

But in one respect the emanation is wholly unlike the other gases with which we are familiar. As already stated it is not permanent, and undergoes a rapid disintgeration, attended with the expulsion of alpha-particles and the formation of non-gaseous but radioactive substances which condense on the surface of negatively-charged bodies.

The presence or absence of such radioactive deposits can only be detected by their power of ionizing air. By highly ingenious methods, it has been possible to determine the law according to which the transformation takes place, and which, as Ramsay puts it, "may be likened to the inverse of the law of compound interest." The average life of the particle of radium emanation has thus been estimated to be five days and nine hours.

Despite the fact that the radium emanation must be classed with the inert gases, it is the most powerful chemical agent known. Weight for weight, it is said to be 100,000 times as active as radium itself; it glows in the dark and, according to Prof. Ramsay, evolves about three million times as much heat as is produced by the explosion of a like volume of a mixture of two volumes of hydrogen and one of oxygen.

There can be no doubt, then, that this emanation should effect chemical changes which have hitherto remained unknown, and in view of what has been said it would not, perhaps, be very surprising to us if we were told that substances hitherto regarded as elements had been "degraded," *i. e.,* resolved into simpler substances, or had been converted into other known elements.

I shall now endeavor to present to you some of the very remarkable observations in this direction which have recently been published by Sir William Ramsay and his collaborators. Their researches concern the action of the radium emanation upon water and upon solutions of certain metallic salts. This work is still in progress, in fact it has hardly passed beyond the stage of a

preliminary survey; yet the facts already brought to light, and the hypotheses suggested by them, seem calculated to shake the very foundations of physical science.

While the radium salts give off but little of the emanation when placed in a dry atmosphere, the transformation-product may be liberated either by heating or by dissolving the salts in water. In the latter case gas is evolved to the extent of say ten c.c. per gramme of radium per day. This gas consists chiefly of a mixture of oxygen and hydrogen, but invariably contains an appreciable excess (of several per cent.) of the latter. Admixed to these gases is a very small proportion of the emanation.

There can be no question that the oxygen and hydrogen are produced by the decomposition of water, but it is difficult to account for the excess of hydrogen; a number of suppositions as to the cause of this have been made, but none of them has stood the test of experimental inquiry.

Thus an interesting experiment was made to ascertain what action the radium emanation might have upon mixtures of oxygen and hydrogen. The gas obtained from a solution of radium bromide was divided into equal parts; one-half was exploded in the burette and it left a residue corresponding to 5.64 per cent. of hydrogen; the other half was sealed up and kept for three weeks, when it was found to have contracted to about two-thirds of its original volume. Thirty per cent. of the gas had recombined, and when the residue was exploded, pure hydrogen to the amount of five per cent. of the original gas remained. This leads to the conclusion that the action of the emanation is a reversible one. The speed of the decomposition, however, must be greater than that of recombination, for otherwise the elements could not be liberated from the water. Thus far all attempts to measure the rate of the decomposition have proved unsuccessful.

Inasmuch as the emanation decomposes water practically in the same manner as the electric current, it occurred to Ramsay that it might also reduce a copper solution and deposit from the latter an amount of metal equivalent to the hydrogen. Contrary to expectations, however, not a particle of copper was precipitated. But when the copper was removed from the solution that had been treated with the emanation, the liquid was found to contain notable amounts of sodium and a trace of lithium. To see whether the presence of these alkali metals was due to the glass or

the materials employed, the experiment was repeated with elaborate precautions to ensure the exclusion of other metals; and blank experiments were also made in which the copper solution was not subjected to the action of the emanation, but otherwise treated in exactly the same way.

On account of the slow action of the emanation it was necessary to extend the experiment over weeks, and even months. A description of these highly interesting experiments may be found in a paper by Cameron and Ramsay, in the September number of the Journal of the Chemical Society. It may suffice here to indicate the most important facts. The copper sulphate or nitrate employed in the several experiments was most carefully purified, as were also the water and the reagents. In one of the experiments only gaseous reagents were used, and all apparatus, except the glass bulb in which the solution was treated with the emanation, were made of platinum or fused quartz. In this case equal parts of a copper nitrate solution were introduced into two bulbs made of the same glass tubing. One of these bulbs was sealed, while four "doses" of emanation were introduced, at intervals of several days, into the other which was then likewise sealed off.

The contents of the first bulb remained clear blue, but the solution treated with the emanation turned slightly turbid and assumed a green color. On being centrifuged in a quartz tube, it yielded 4.11 mg of solid residue. This was found to consist of a basic copper salt. The solution separated from the latter was freed from copper by means of hydrogen sulphide and evaporated. The residue weighed 1.67 mg and consisted chiefly of a sodium salt, with traces of calcium and lithium. Ramsay estimates the amount of lithium at .00037 mg.

The blank experiment yielded only .97 mg of residue, and while this gave the spectra of sodium and calcium, it was found to be entirely free from lithium.

Somewhat similar experiments were made with solutions of lead nitrate, but although the formation of minute quantities of "six-sided colorless tables, and reddish yellow grains" was noticed, after a treated solution of the nitrate had been freed from lead, this residue was too small to allow of further investigation. By using larger quantities of the emanation and substituting bulbs made of silica the authors hope to obtain, from both the copper and the lead solutions, such amounts of the products as will permit

them to arrive at more definite conclusions. Such experiments are now in progress, and it may be expected that they will yield most interesting results.

While popular attention and curiosity have been excited mainly, if not entirely, by the apparent transformation of the metals under the influence of the radioactive emanation, no less significant facts have been brought to light by the study of the gaseous products of this action.

The gases investigated by Ramsay and Cameron were the residues left after treating with emanation, in glass tubes, pure distilled water, and solutions of the nitrates of copper and lead.

The "copper gas" obtained by pumping out the bulb containing the treated solution of the nitrate, was found to contain considerable quantities of nitric oxide, which must have resulted from a reduction of the nitrate ion. This oxide of nitrogen, as well as the oxides of carbon. and the oxygen, hydrogen and nitrogen, were carefully removed, and their amounts determined. The analysis gave:

Nitric oxide	1.12 c.c.
Nitrogen	.34 "
Carbon dioxide	.27 "
Hydrogen	.44 "
Oxygen	1.12 "

The spectrum of the residue was that of pure argon. While this gas and the nitrogen may have leaked in through the stopcocks of the apparatus, Ramsay does not incline to this view, but believes that the nitrogen was derived from the nitrate and that the argon resulted from the "degradation" of the emanation.

The gas from the "treated" water was found to contain:

Nitrogen	.307 c.c.
Carbon dioxide	.065 "
Carbon monoxide	.030 "
Hydrogen	3.746 "
Oxygen	1.562 "

The residue left after the removal of these gases gave a brilliant spectrum in which every line of neon and some of the yellow and green lines of helium could be identified.

As to the gas extracted from the bulb in which lead nitrate had

been treated with emanation, it contained neither nitric oxide nor carbon monoxide, and it was not tested for inactive gases.

If we accept the idea that the radium emanation is a gaseous element of high atomic weight and belonging to the argon group, we may consider the production of helium, neon, and argon—the lower members of the series—to be due to the atomic disintegration or "degradation" of that element. This change would occur under circumstances which are totally different from those attending ordinary chemical action. It might be attributed to the spontaneous and explosive emission of alpha particles from the radium, and the subsequent bombardment of the larger atoms of the emanation by these particles. Some hold that these particles are identical with helium, but Ramsay considers this improbable. Helium is formed when the emanation is left alone, or when it is mixed with oxygen and nitrogen. But when particles of greater mass than oxygen and hydrogen are present, the degradation does not proceed so far; in presence of molecules of liquid water it yields neon, and when the emanation acts upon still denser and more complex molecules, as in a solution of copper sulphate, argon is produced. At the same time, it would appear, the heavier atoms that come into collision with the alpha particles likewise succumb to their disrupting power. Thus the copper ions in the sulphate solution appear to be slowly transformed into the lighter atoms of the alkali metals, sodium and lithium.

Another most remarkable observation of this kind is that an acid solution of thorium nitrate continuously gives off carbon dioxide gas.

No experimental evidence can yet be adduced to show that the transformations of the elements are reversible processes; we know of no case in which the heavier atoms have been built up from lighter and more elementary ones. The "dream of the alchemists" of the transformation of the base into noble metals has not been realized.

Nevertheless, it does not appear unreasonable to suppose that there may be conditions under which the radioactive elements of high atomic weight, are formed from elements of smaller atomic weight. On the supposition that radium, and perhaps bismuth and lead, result from uranium and thorium by the loss of definite amounts of helium—which some believe to be identical with the

alpha-particles—it might be argued that these elements could also be built up by the addition to the radium atom of the requisite number of helium atoms. According to Rutherford, "it thus appears that helium plays a most important part in the constitution of the radioelements, and it is not unlikely that helium as well as hydrogen may ultimately prove one of the more elementary units of which the heavy atoms are built up."

With this, however, we enter the field of speculation.

The application of radioactivity to the solution of chemical problems is still in its beginnings, but I think there can be no doubt that we are on the threshold of a new period in the history of our science, a period inaugurated by what Landolt has recently pronounced "the most remarkable chemical discovery since the true nature of combustion was established"—the radioactive transformation of one elementary substance into another.

I have endeavored to confine my account to the purely chemical side of the subject, and have purposely refrained from a discussion of the probable causes and the mechanism of atomic distegration. If I have succeeded in piloting you to the most prominent points of interest in this new field of chemical research, my object is fully accomplished.

At the close of the lecture a number of slides were shown illustrating the history of the subject and the apparatus employed by the investigators.

WHITE FIR AS PULP WOOD.

On the Pacific Coast, especially in Oregon and California, there is an immense amount of white fir *(Abies concolor)* timber now going to waste for lack of some commercial profitable means of disposing of it. At present it is very little used for lumber, and since it is not cut to any extent its proportion in the forest tends to increase at the expense of other and more valuable trees.

Experiments conducted at the Forest Service laboratory at Washington show that this wood is admirably adapted for the production of paper pulp by the sulphite process. The wood is found to yield very readily to the action of the sulphite liquors used, which is of the usual commercial strength, viz.: about 4.0 per cent. total sulphur dioxide, 1.0 per cent. combined and 3.0 per cent. available. The length of treatment has varied, in the different tests, from eight to ten hours, and the steam pressure from 60 to 75 pounds. These pressures correspond to maximum temperatures of 153 to 160 degrees C.

The pulp produced in these experiments is from nearly white to light brown in color, according to the variations in the method of cooking, and by selecting the proper conditions of treatment it would be readily possible to produce a grade of fibre which could be used in many kinds of paper without the least bleaching. If, however, it is desired to employ the fibre for white book or writing papers it could be readily bleached to a good white color. Results of laboratory tests show that the bleach required to bring the fibre up to the usual color for bleached sulphite spruce fibre is from 15 to 23 per cent. to the weight of unbleached fibre; that is, assuming the bleaching powder to contain 35 per cent. available chlorine. Sulphite spruce fibre now on the market requires from 175 to 500 pounds of 35 per cent. bleach per ton of product or from 9 to 24 per cent. of the unbleached fibre. It is seen, therefore, that so far as bleaching is concerned the pulp made from white fir is just as good as that made from spruce.

The yields obtained in these experiments ranged from 43 to 49 per cent. on the bone dry basis. This is exclusive of screenings which in no case exceed 1¼ per cent. of the dry wood used. From careful observation of the methods employed in determining the yields it seems probable that those figures will be increased slightly when larger quantities of wood are used and it is believed that in the matter of yield the fir wood is fully equal to spruce.

The fibre from these cooks is in most cases light colored and somewhat lustrous and the sheets formed from it without any beating are remarkably tough and strong. Microscopic examination and measurements show that the fibre are of very remarkable length, being from one-half to two-thirds as long again as the commercial sulphite spruce fibre.

It is believed from the results that, so far as the product is concerned, the manufacture of fibre from white fir would be a commercial success and that the fibre produced would find its greatest usefulness in the production of manilas where great strength is required and in tissues which need very long fibres. It seems probable, also, that it would make very good newspaper for which purpose its naturally light color would particularly adapt it.

CONGRESS OF REFRIGERATING INDUSTRIES.

The First International Congress of the Refrigerating Industries is to be held in Paris, France, October 5 to 10, 1908, under the patronage of the French Minister of Agriculture, Commerce and Industries.

The purpose of the Congress is to bring together the leading experts and representatives of the different industries and enterprises of all countries in which refrigeration is used as an agent for facilitating the preservation and transportation of food products by land or sea. It is believed that such a Congress will be likely to stimulate the best thought in the world on the subject of refrigeration, and through such a conference of practical and scientific men it is hoped to improve and perfect the production and application of mechanical refrigeration.

The topics to be considered by the Congress are as follows: Low temperatures and their general effects; refrigerating appliances; the application of refrigeration to food; the application of refrigeration to other industries; application of refrigeration in commerce and trantport; and legislation.

(Stated meeting held Thursday, March 5, 1908.)

New Aids For Navigation.*

HENRY EMERSON WETHERILL, M.D.

Lt. Surg., and Inspector of Rifle Practice, "Naval Force of Pennsylvania." Candidate for Master Mariner, U. S.

A Special Semicircle, Called Angleometer.—Having but one reflector which serves both as index and horizon glass, this instrument is free from the corrections accompanying the horizon glass of other instruments, can be made without scale yet accurate enough for meridional lunar declination for Greenwich time.

As the ray of light is reflected but once the luminosity for stellar observations is decidedly advantageous, thereby increasing three fold the number of stars that may be used. Approved by the best men, with whom I have consulted.

The special vernier reading to 170 degrees enables observations of heavenly bodies of high altitude, and with the artificial horizon.

There being no parallax, as with other instruments, makes it good for land surveys, as in measurements of near-by objects.

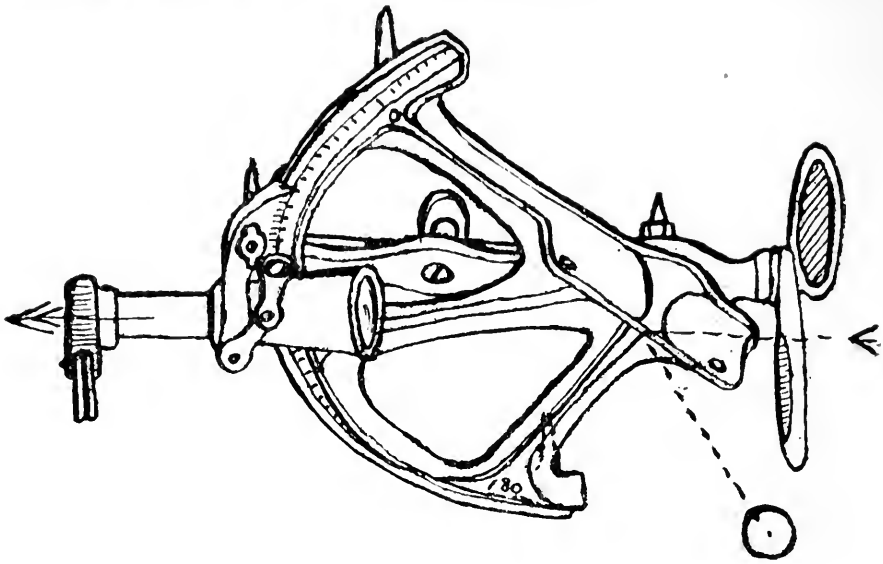
The simplicity of construction and method of making the micrometer enables the instrument to be sold at a price one-third off the present instruments, and will be a boom to the American production of these instruments, now almost wholly made abroad.

This instrument is made to withstand the severest service, and its freedom from the many corrections of other instruments renders it more easily applicable by the average seaman.

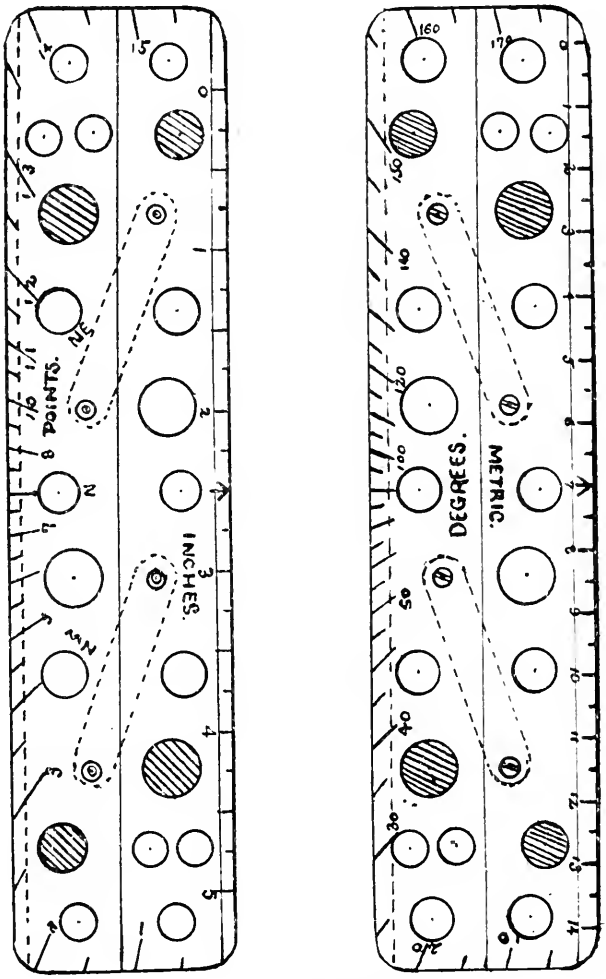
A Parallel Rule, that will work with either side down, and that is capable of advancing straight across the chart, whether the rule

---

*Working models submitted; sketches of various forms accompany this paper.



Angleometer.



Two- sided Parallel Rule.

is open or closed. It is thick enough to enable you to tip it in going over obstacles.

It is preferably made of seasoned, quartered, straight grained Santo Domingo mahogany, with the three pieces arranged with the grain in opposite positions, to prevent warping, and the bars set in the center of the rules. The screws are arranged to take up wear. The corners are rounded, and the rules peforated to enable you to see the chart, and for the insertion of pads to prevent slipping of the rule.

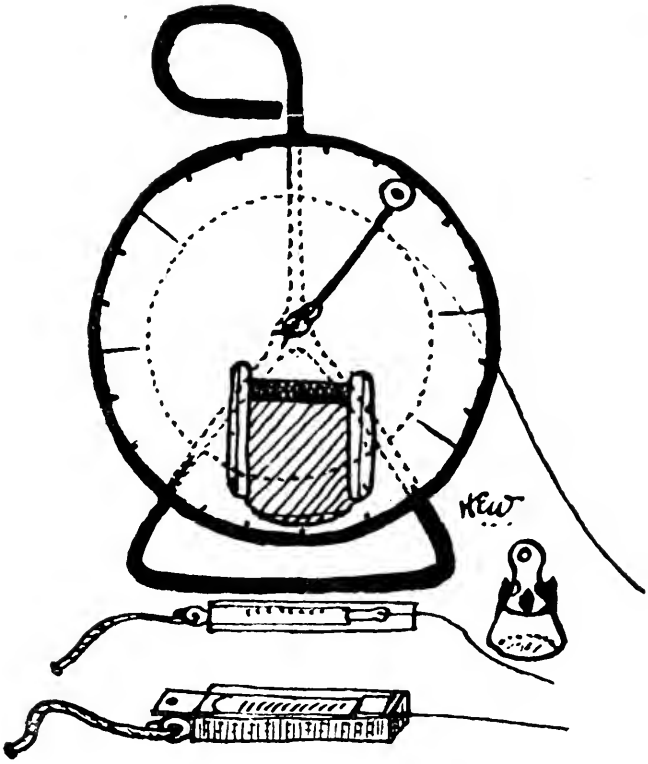
Metal edges may be graduated in centimeters, degrees, points, and inches, as with other rules, using both sides.

A Self-Inking Roller, called the Rotalin, is a disc that facilitates the inking or penciling in of the Naperian compass correction curve, or the drawing or measurement of any mathematical curve, boat model outline, great circle course, line on squared paper, or chart course. The dotting form will enable observations to the fraction of a second, as in time sights. It enables a better estimation of leeway and serves as a dead reckoning course corrector. One form gives ships' heel and roll.

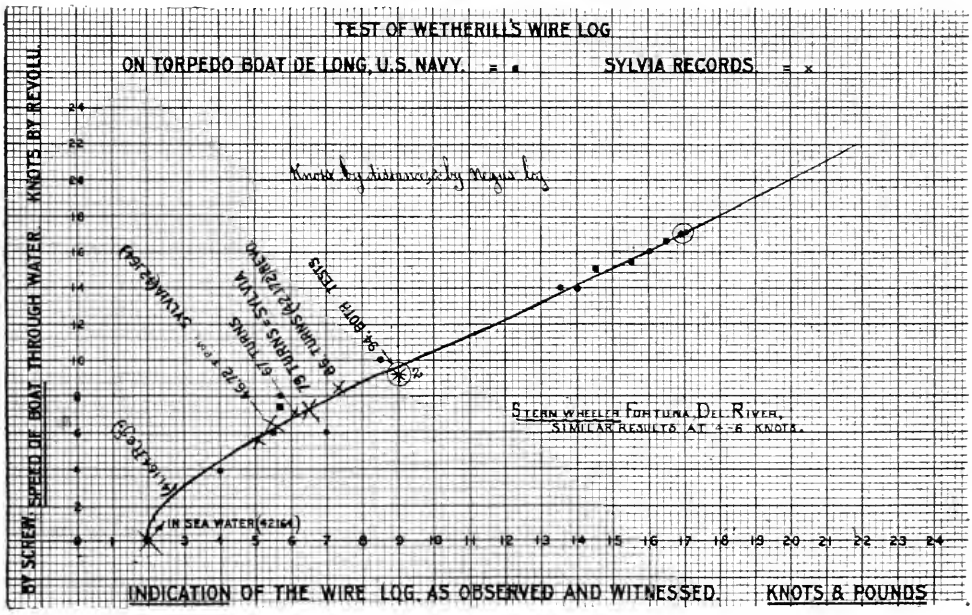
A Practical Speed Log, Called the Tafsped.—It has been found that accurate measurements of speed of ships can be made by towing a wire of sufficient length, flexibility, non-corrosibility, and diameter to have the pound dynamometer show knots. The instrument exhibited is the most perfected form of this speed indicator. The wire may be used for soundings, and measurements from the bottom for speed may be made, nature of bottom determined.

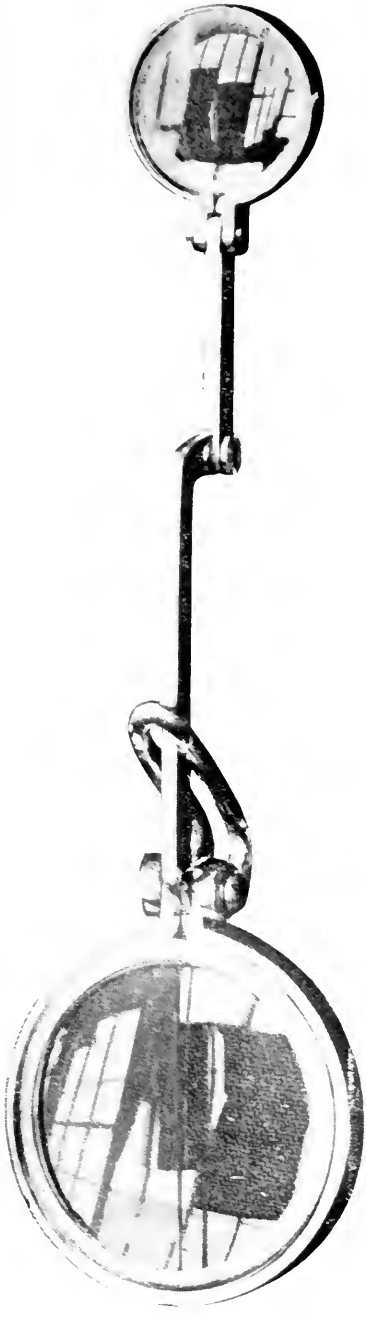
The speed of ship at instant before rifle fire is readily read off. The log will not catch seaweed, nor jump out of the water. It works equally well in fresh or salt water, is low in price, and not complicated. It overcomes the disadvantages of drags formerly tried. The propeller thrusts cause no jiggle of the indicator. The boat is held back less than with other logs; being about one pound for each knot. It is applicable to different boats of different speeds. It has been carefully tested. There is plenty of power for use of recording dial, if wished. It is the reciprocal of the taffrail distance log.

A Range-Finder, Called the Safper Glass, is made up in several ways, the principle being that a prism separates the objects as 1 is to 100 and a scale is used to measure the separation.

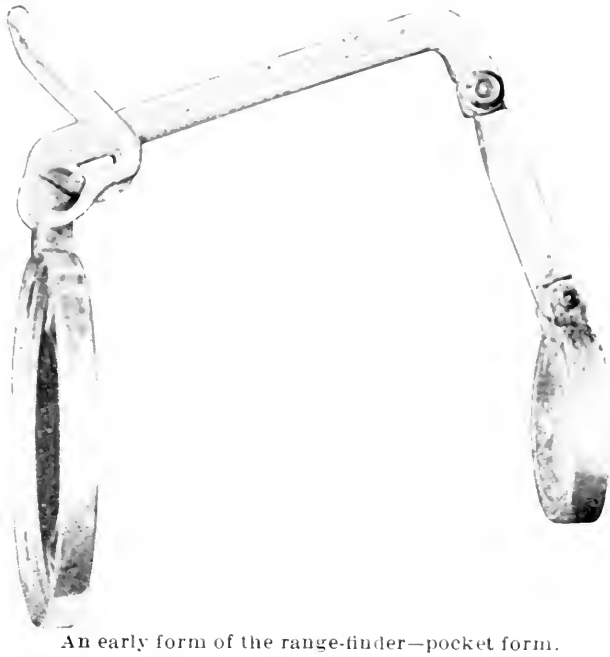


Wirs speed log.

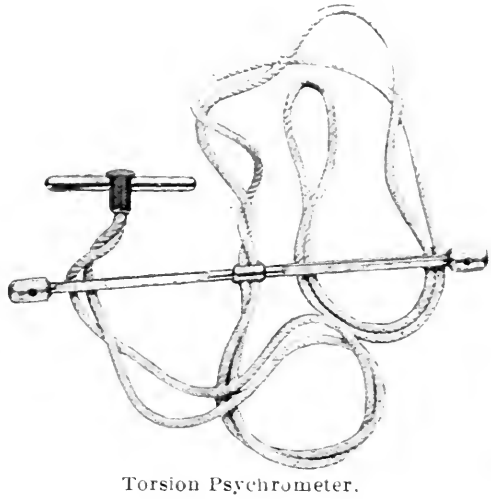




Pocket form of the 1 degree range glass. Achromatic combination is 4D—20D. Power of 4.5 diam.



An early form of the range-finder—pocket form.



Torsion Psychrometer.

Universal thermometer—without the metal tube on scale.

This is the first application to the Galilean telescope, and a special pocket folding form is submitted. Now made to open up at once and into focus.

In rough weather the prism and scale are used without magnification, as in the telescope presented.

The great advantage is the application to any terrestrial or astronomical instrument *in use,* the ridicule being in the focus of the ocular. It is applicable to the prism glass.

This instrument keeps up its accuracy to any distance, and thus supersedes others which depend upon a short base line.

It will not get out of order, and does not have any delicate moving parts susceptible to jar of rifle fire.

The separation of the objects is a better principle than the use of stadia lines on objects of known size. Each glass has its own constant. A series of prisms may be used.

The Torsion Psychrometer submitted will give the maximum and minimum thermometer readings, being suspended free of the ship's motion, and on the cords that give the revolutions. Thus no gearing is necessary, and the results are more accurate than with such stationary hygrometers as Mason's. The dew point is more accurately determined by using the silver cap on the wet bulb. The maximum thermometer's needle is brought down centrifugally, not requiring a magnet. (Full description see Wetherill's hygromedry.)

The Chloride of Cobalt Hygroscope exhibited will enable the navigator to rate his chronometer for humidity. No calculation is required, as in measuring the moisture of the air. The dampness of powder, and the atmosphere of the magazine is shown at a glance. It has been used for several years in allowing for the change of elevation of the rifle, with meteorological conditions. It would aid researches on the correction of the lower limb of sex-

tant angles, correcting for refraction there. (Ether from nitro powder no source of error.)

An instrument called the *Typeel* has been found advantageous in clearly showing the change of course due to the compass errors; it enables the compass adjuster to furnish a clear visible correction card. See cuts. Handy for insertions in manifest or bill of lading.

This typewriter will write seventeen words a minute, and in making headings for nautical computations to be kept in the special loose-leaf book submitted, it is advantageous.

It is vest-pocket size, and makes clear entries in the log, and tabulates in any square of the paper desired. It will make nota-

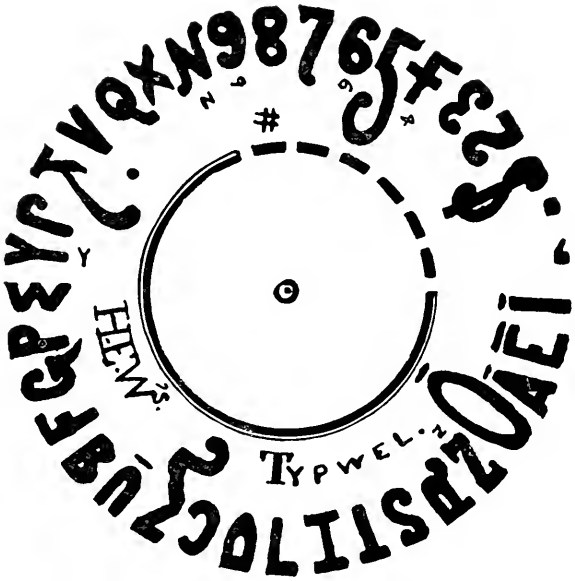
Cobalt Hygroscope dial.

tions on any sized charts and labelling the end of the charts with it facilitates the withdrawal of the chart desired from the special chart case shown. Music type shown, and cards of arrangement of letters exhibited. It will stencil phonetic Japanese.

The Celluloid Protractor Position Finder is a more practical method for the seaman to work the three or four point problems without the expense of cumbersomeness of other protractors. It will give the course, work a cross bearing, and protect the chart from rain.

It is a very large accurately scratched protractor, with radii so long that movable arms are unnecessary.

An early form, since much improved by slanting the letters, using a wire stem. Water refreshes the purple aniline reservoir. Letter spaces, interchangable for printing or translating cryptograms.



Arrangement of characters in the order of their use, which also helps solve cryptograms.

Typwel letters

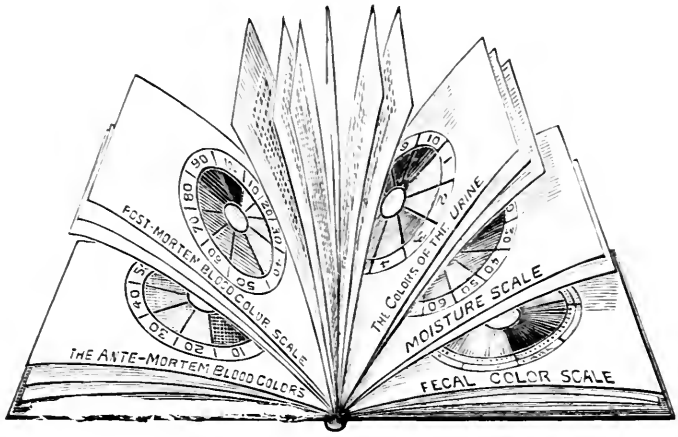
& Z J X Q K V G B P Y W M F C U L D R H O I A S T N E , . - $ 1 2 3 4 5 6 7 8 9 0

Arrangement of musical characters for the typwel in the order of their use. Can be placed on any line.

The graduations are filled with heel ball to make them visible. It is in one sheet and readily stows with the charts.

Sextant Attachments, as follows: Prism for adding constant angle for artificial horizon work in the tropics. Scale for locating a sextant, free from parallax thereof. Revolving stand for holding instrument. Glass level tube for finding horizon on land; new form with specially constricted tube.

The Artificial Horizon of glass, with base in the form shown, was found the very best way to use this method, and after trying various forms on different expeditions, it is found for an ordinary sun hour angle accurate to the fraction of a second of time. The bottom surface is specially ground and painted with a non-reflecting black. The three leveling corners having handles to the



Color scales.

screws show how much turning there is to get the desired effect upon the two large, reversible levels. This same surface reflection is used upon the angleometer, and obviates prismatic error of glass, and double reflection, as in the poorer principle of ordinary sextants.

The Light Measurer will enable an entrance in the log of the mathematical expression of the daylight. By counting the number of celluloids that will just prevent the determination between a black and a white cordan entry of the obscurity due to fog is made in the same manner as the instrument is made to express the lenticular opacity in opthalmology. In rifle work the gun pointer sights according to the light, naturally taking less front sight with more light, and this scale shows the amount of light. In a bright light nine celluloids are penetrated, and in ordinary office light only

four. It serves as a basis to work upon in estimating actinic power of light for the photographer of colors; a more compact and protected form for this purpose, recently marketed.

It is useful for keeping a record of light, as often at sea storms are preceded by less and less light. (See proceedings Pa. Bot. Soc., 1908, "Measurement of Light in Greenhouses.")

An aid to the use of Bowditch's tables is to have tabs with the number of the table on the edges of the pages.

The Horizontal Calipers shown have an enormous stretch for chart work and a scale upon them will show the extension. The limb can be clamped on either end of the slide groove, and the instrument can be worked with one hand.

The Scurvy test is the most accurate and practical Hemoglobin scale, and in the same book is bound the relative humidity scale, and other color scales. In the second edition, now going to press, is being added for naval surgeons all other color scales of use to them at sea. Hemoglobin scale corrected on all percentages at Panama.

I submit a table of decimal fractions of unity with logs to seven places, for use in calculations.

PRODUCTION OF MAGNESITE IN 1906.

All the magnesite produced in the United States comes from California, but the quantity is not large, since the consumption is small on the Pacific Coast, and the native product cannot compete at points of greatest consumption east of the Missouri River with that imported from Greece and Austria, owing to prohibitive freight rates from California.

The deposits at Porterville, Tulare County, yield most of the crude and calcined material, though a few thousand tons are derived from the Red Mountain deposits in Alameda County. Some calcined material is also sold by the manufacturers of carbonic acid gas, who, however, obtain their crude magnesite from the Porterville deposits. At Porterville there are kilns where the calcining is done. The calcined material is mainly used as a digester for wood pulp in paper manufacture. For carbonic acid gas manufacture about 800 tons are consumed yearly. The crude magnesite costs in the San Joaquin Valley about $3 a ton, and the freight to San Francisco Bay is $3 a ton. The calcined product sells for a lower price than formerly; at San Francisco it brings $14 per ton f.o.b. Higher prices for labor and mining now add about $1 per ton to the cost of the crude material. The calcined magnesite varies in price according to the amount of roasting given it, and that specially calcined and given a longer roast at a

DECIMALS OF UNITY, PROCEEDING WITH A DIFFERENCE OF 1/128.

No.	Inch.	Decimal.	Logarithm.	Logarithm.	Decimal.	Inch.	No.
0	0	0	0	0	1.0	1.0	128
1	1/128	.007 812	7.892 7900	9.996 5905	.992 187	127/128	127
2	1/64	.015 625	8.193 8200	9.993 1584	.984 375	63/64	126
3	3/128	.023 437	8.369 9113	9.989 6989	.976 562	125/128	125
4	1/32	.031 250	8.494 8500	9.986 2117	.968 750	31/32	124
5	5/128	.039 062	8.591 7600	9.982 6918	.960 937	123/128	123
6	3/64	.046 875	8.670 9413	9.979 1476	.953 125	61/64	122
7	7/128	.054 687	8.737 8841	9.975 5743	.945 312	121/128	121
8	1/16	.062 500	8.795 8800	9.971 9713	.937 500	15/16	120
9	9/128	.070 312	8.847 0295	9.968 3335	.929 687	119/128	119
10	5/64	.078 125	8.892 7900	9.964 6697	.921 875	59/64	118
11	11/128	.085 937	8.934 1802	9.960 9747	.914 062	117/128	117
12	3/32	.093 748	8.971 9620	9.957 2480	.906 252	29/32	116
13	13/128	.101 560	9.006 7227	9.953 4842	.898 439	115/128	115
14	7/64	.109 373	9.038 8982	9.949 6924	.890 627	57/64	114
15	15/128	.117 185	9.068 8535	9.945 8672	.882 814	113/128	113
16	1/8	.124 998	9.096 8753	9.942 0081	.875 002	7/8	112
17	17/128	.132 810	9.123 2308	9.938 1093	.867 189	111/128	111
18	9/64	.140 623	9.148 0471	9.934 1802	.859 377	55/64	110
19	19/128	.148 435	9.171 5217	9.930 2153	.851 564	109/128	109
20	5/32	.156 248	9.193 7922	9.926 1211	.843 753	27/32	108
21	21/128	.164 060	9.215 0027	9.922 1699	.835 939	107/128	107
22	11/64	.171 873	9.235 2001	9.918 0933	.828 127	53/64	106
23	23/128	.179 685	9.254 4997	0.913 9780	.820 314	105/128	105
24	3/316	.187 498	9.272 9781	9.909 8234	.812 502	13/16	104
25	25/128	.195 310	9.290 7245	9.905 6232	.804 689	103/128	103
26	13/64	.203 123	9.307 7527	9.901 3875	.796 877	51/64	102
27	27/128	.210 935	9.324 1384	9.897 1100	.789 064	101/128	101
28	7/32	.218 748	9.339 9282	9.892 7900	.781 252	25/32	100
29	29/128	.226 560	9.355 1832	9.888 4210	.773 439	99/128	99
30	15/64	.234 373	9.369 9020	9.884 0133	.765 627	49/64	98
31	31/128	.242 185	9.384 1383	9.879 5603	.757 814	97/128	97
32	1/4	.249 998	9.397 9226	9.875 0613	.750 002	3/4	96
33	33/128	.257 810	9.411 2998	9.870 5092	.742 189	95/128	95
34	17/64	.265 623	9.424 2608	9.865 9149	.734 377	47/64	94
35	35/128	.273 435	9.436 8462	9.861 2715	.726 564	93/128	93

DECIMALS OF UNITY, PROCEEDING WITH A DIFFERENCE OF 1/128.

No.	Inch.	Decimal.	Logarithm.
0	0	0	0
1	1/128	.007 812	7.892 7900
2	1/64	.015 625	8.193 8200
3	3/128	.023 437	8.369 9113
4	1/32	.031 250	8.494 8500
5	5/128	.039 062	8.591 7600
6	3/64	.046 875	8.670 9413
7	7/128	.054 687	8.737 8841
8	1/16	.062 500	8.795 8800
9	9/128	.070 312	8.847 0295
10	5/64	.078 125	8.892 7900
11	11/128	.085 937	8.934 1802
12	3/32	.093 748	8.971 9620
13	13/128	.101 560	9.006 7227
14	7/64	.109 373	9.038 8982
15	15/128	.117 185	9.068 8535
16	1/8	.124 998	9.096 8753
17	17/128	.132 810	9.123 2308
18	9/64	.140 623	9.148 0471
19	19/128	.148 435	9.171 5217
20	5/32	.156 248	9.193 7922
21	21/128	.164 060	9.215 0027
22	11/64	.171 873	9.235 2001
23	23/128	.179 685	9.254 4997
24	3/316	.187 498	9.272 9781
25	25/128	.195 310	9.290 7245
26	13/64	.203 123	9.307 7527
27	27/128	.210 935	9.324 1384
28	7/32	.218 748	9.339 9282
29	29/128	.226 560	9.355 1832
30	15/64	.234 373	9.369 9020
31	31/128	.242 185	9.384 1383
32	1/4	.249 998	9.397 9226
33	33/128	.257 810	9.411 2998
34	17/64	.265 623	9.424 2668
35	35/128	.273 435	9.436 8462
36	9/32	.281 248	9.449 0771
37	37/128	.289 060	9.460 9880
38	19/64	.296 873	9.472 5663
39	39/128	.304 685	9.483 8439
40	5/16	.312 498	9.494 8361
41	41/128	.320 310	9.505 5705
42	21/64	.328 123	9.516 0327
43	43/128	.335 935	9.526 2488
44	11/32	.343 748	9.536 2301
45	45/128	.351 560	9.545 0995
46	23/64	.359 373	9.555 5418
47	47/128	.367 185	9.564 8790
48	3/8	.374 998	9.574 0197
49	49/128	.382 810	9.582 9833
50	25/64	.390 623	9.591 7545
51	51/128	.398 435	9.600 3520
52	13/32	.406 248	9.608 7827
53	53/128	.414 060	9.617 0633
54	27/64	.421 873	9.625 1786
55	55/128	.429 685	9.633 1451
56	7/16	.437 498	9.640 9681
57	57/128	.445 310	9.648 6624
58	29/64	.453 123	9.656 3132
59	59/128	.460 935	9.663 6350
60	15/32	.468 748	9.670 9320
61	61/128	.476 560	9.678 1176
62	31/64	.484 373	9.685 1772
63	63/128	.492 185	9.692 1240
64	1/2	.500 000	9.698 9700

Logarithm.	Decimal.	Inch.	No.
0	1.0	1.0	128
9.996 5905	.992 187	127/128	127
9.993 1584	.984 375	63/64	126
9.989 6989	.976 562	125/128	125
9.986 2117	.968 750	31/32	124
9.982 6918	.960 937	123/128	123
9.979 1476	.953 125	61/64	122
9.975 5743	.945 312	121/128	121
9.971 9713	.937 500	15/16	120
9.968 3335	.929 687	119/128	119
9.964 6667	.921 875	59/64	118
9.960 9747	.914 062	117/128	117
9.957 2480	.906 252	29/32	116
9.953 4842	.898 439	115/128	115
9.949 6924	.890 627	57/64	114
9.945 8672	.882 814	113/128	113
9.942 0081	.875 002	7/8	112
9.938 1093	.867 189	111/128	111
9.934 1802	.859 377	55/64	110
9.930 2153	.851 564	109/128	109
9.926 1211	.843 753	27/32	108
9.922 1699	.835 939	107/128	107
9.918 0933	.828 127	53/64	106
9.913 9780	.820 314	105/128	105
9.909 8234	.812 502	13/16	104
9.905 6232	.804 689	103/128	103
9.901 3875	.796 877	51/64	102
9.897 1100	.789 064	101/128	101
9.892 7900	.781 252	25/32	100
9.888 4210	.773 439	99/128	99
9.884 0133	.765 627	49/64	98
9.879 5603	.757 814	97/128	97
9.875 0613	.750 002	3/4	96
9.870 5092	.742 189	95/128	95
9.865 9149	.734 377	47/64	94
9.861 2715	.726 564	93/128	93
9.856 5779	.718 752	23/32	92
9.851 8268	.710 939	91/128	91
9.847 0295	.703 127	45/64	90
9.842 1785	.695 314	89/128	89
9.837 2727	.687 502	11/16	88
9.832 4323	.679 689	87/128	87
9.827 2852	.671 877	43/64	86
9.822 2073	.664 064	85/128	85
9.817 0693	.656 252	21/32	84
9.811 8631	.648 439	83/128	83
9.806 6005	.640 627	41/64	82
9.801 2733	.632 814	81/128	81
9.795 8800	.625 002	5/8	80
9.790 4118	.617 189	79/128	79
9.784 8811	.609 377	39/64	78
9.779 2790	.601 564	77/128	77
9.773 6036	.593 752	19/32	76
9.767 8457	.585 939	75/128	75
9.762 0180	.578 127	37/64	74
9.756 1110	.570 314	73/128	73
9.750 1225	.562 502	9/16	72
9.744 0425	.554 689	71/128	71
9.737 8841	.546 877	35/64	70
9.731 6371	.539 064	69/128	69
9.725 2689	.531 252	17/32	68
9.718 8586	.523 439	67/128	67
9.712 3298	.515 627	33/64	66
9.705 7012	.507 814	65/128	65
9.698 9700	.500 000	1/2	64

Constant difference of the decimals is 0.007 8125.

On one side of the table is the fraction, opposite is the amount to make it up to unity.

In multiplying fractions it is handier to use this table than to hunt up each item in a large logarithm table.

This table is founded on Baron Von Vega's mathematical tables.

The decimals were calculated to seven places, and then written down as six place decimals.

The use of an accurate decimal lessens the multiplication of an error.

higher temperature brings a higher price than that resulting from the manufacture of carbonic acid gas.

The total domestic output of crude magnesite in 1906 was 7805 short tons, valued at $23,415, an average of $3 per ton, as against 3933 short tons, valued at $15,221, in 1905. Most of this was roasted, resulting in 2864 tons of calcined magnesite for use as a digester of wood pulp and for making brick and building material. It usually requires 2.4 tons of raw magnesite ($MgCO_3$) to make 1 ton of calcined magnesite (MgO). This 2864 tons of calcined material was valued at $40,000, or between $13 and $14 per ton. Small lots were, however, sold at lower prices.

The imports of magnesite into the United States in 1906, including crude and calcined material and medicinal magnesite, amounted to 186,692,947 pounds, valued at $897,497, figures which represent substantial increases over those for 1905. The United States Consul at Vienna, Austria, states that the exports of calcined magnesite to the United States from the Vienna Consular district alone amounted to 53,000 tons, net weight, and that the principal company operating the magnesite mines in Austria is enjoying extraordinary prosperity.

A report on the production of magnesite in 1906, prepared by Charles G. Yale, is published by the United States Geological Survey as an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is n w ready for distribution.

INVESTIGATIONS OF COAL FIELDS.

The coal fields of thirteen States and Territories were examined by geologists of the United States Geological Survey in 1906, and the results of this work have just been published by the Survey as Bulletin No. 316, which forms Part II of "Contributions to Economic Geology, 1906."

The importance of the coal industry at the present time is well illustrated by a comparison of the values of the leading mineral products of the United States for the year 1906.

VALUES OF SIX OF THE LEADING MINERAL PRODUCTS OF THE UNITED STATES IN 1906.

Coal	$513,079,809
Iron	505,700,000
Copper	177,595,888
Clay products	161,032,722
Oil and Gas	137,318,667
Gold and Silver	132,630,200

So far as fuels are concerned the work of the Geological Survey is divided into three classes, geologic, technologic, and statistical, the last of which is in charge of the division of mineral resources, whose work for 1906 yielded the figures given above.

All the geological work on mineral fuels of the United States is under the general supervision of Mr. M. R. Campbell. The work is of various grades and degrees of precision, depending on the needs of the public and the conditions under which the surveys are carried on.

In the region west of the 100th meridian the coal fields are comparatively unknown and the work of the Survey is largely exploratory. Rapid reconnaissance surveys are made over large areas to determine the limits of the field and to obtain such information regarding the number and character of the coal beds and their attitude as may be possible in the present undeveloped condition of the field and with the hasty method of examination. In the eastern fields information is needed almost as badly as in the West, but the work is of a much more detailed character and involves not only a thorough study of the geologic conditions under which the coal occurs, but also a study of the quality of the coal and its adaptability to various commercial uses.

The report just published covers results obtained wholly or in part during 1906 and includes 28 separate papers. Twenty-four of these describe coal fields in Pennsylvania, Kentucky, Virginia, Alabama, Illinois, Arkansas, Montana, Wyoming, Colorado, Utah, New Mexico, and California; three are papers of a general nature, and one—the last—is a list of the Survey publications on coal, lignite, and peat.

Bulletin No. 316 is now ready for distribution and may be obtained by applying to the Director, U. S. Geological Survey, Washington, D. C.

ENGELMANN SPRUCE AS A PULP WOOD.

Engelmann spruce is a comparatively small tree of rather slow growth whose range is on the high slopes of the interior mountain system from British Columbia southward to Arizona and New Mexico. Within this range it is used to some extent for lumber, mining timber, ties, and general construction, but it has not been considered a very valuable lumber tree, and it is employed only because of lack of better material. No estimate of the total amount of standing timber is available, but reports of stands show more than one and one-half billion board feet as occurring on four of the National Forests, and this is probably only a small part of the actual quantity standing. Throughout its entire range there is much material in the form of dead and mature timber.

The existence of such quantities of a wood of seemingly little value has induced the United States Forest Service to undertake experiments to determine whether this wood can be used for making paper pulp. Samples have been received from the National Forests of Wyoming, Colorado and Utah. These have been treated by the sulphite process, and a pulp has been obtained which, unbleached, is in color nearly as good as pulp made from Eastern spruce under similar conditions, and in strength, cleanliness, and other qualities seems to be fully as good. The results of preliminary trials on seasoned wood show that it cooks without difficulty and gives a yield of fibre nearly equal in volume to that from its eastern relative. The amount of screenings is very small, being between two and three per cent. Tests made on the fibre show that it bleaches quite easily, the amount of bleach varying with different cooks, but in general it may be said to require about the same quantities as fibre produced from Eastern spruce.

A few cooks have been made on green wood, cooked within two months

of the time the trees were cut, and the indications are that it will require a little higher temperature than the seasoned wood. The fibre produced from green wood, however, seems to be fully equal to that from seasoned wood, and is superior to it in color.

The fibre of Engelmann spruce seems to be slightly shorter than that from Eastern spruce, but it is of sufficient length to be used for the latter in nearly all the manufactured products, and there is apparently no reason why it should not be so used, provided the other conditions of manufacture and transportation are favorable.

Book Notices.

PUBLICATIONS RECEIVED.

Providence, R. I. Annual Report of City Engineer for the year 1907. 83 pages, illustrations, plates, maps, tables, 8-vo. Providence, City Printers, 1908.

U. S. Department of Agriculture:

Forest Service, Bulletin No. 77. Forest Products of the United States, 1906. 99 pages, tables, 8-vo. Washington, Government Printing Office, 1908.

Circular No. 143. The Relation of the Southern Appalachian Mountains to Inland Water Navigation, by M. O. Leighton and A. H. Horton. 38 pages, 8-vo. Washington, Government Printing Office, 1908.

Circular 144. The Relation of the Southern Appalachian Mountains to the Development of Water Power, by M. O. Leighton, M. R. Hall, and R. H. Bolster. 53 pages, 8-vo. Washington, Government Printing Office, 1908.

Complete classified index of Power Plant Equipment, including everything needed in engine and boiler rooms, power transmission systems and supplies, with addresses of manufacturers. Compiled from the advertising of live firms in "Power." 53 pages, 16-mo. New York, n. d.

Conservation of Historic Buildings and Frescoes, by Prof. A. H. Church. An address delivered before the Royal Institution of Great Britain, April 12, 1907 12 pages, 8-vo.

International Science, by Prof. Arthur Schuster. An address delivered before the Royal Institution of Great Britain, May 18, 1906. 22 pages, 8-vo.

L'Ébullition des Corps Simples. An address delivered before the Royal Institution of Great Britain by Prof. H. Moissan, June 1, 1906. 15 pages, illustrations, 8-vo.

Kurzes Lehrbuch der Organischen Chemie von William A. Noyes, Professor der Chemie an der Universität Illinois. Mit Genehmigung des Verfassers ins Deutsche übertragen von Walter Ostwald und mit einer Vorrede von Professor Wilhelm Ostwald. 722 pages, illustrations, 8-vo. Leipzig, Akademische Verlagsgesellschaft. m. b. H. 1907.

The present volume is a translation of Dr. Noyes' well-known "Text-

book of Organic Chemistry." The task of rendering it into German was undertaken by Walter Ostwald, who was able to secure the coöperation of the author in the matter of improvements and corrections.

Only such changes were made as were found necessary to bring the book in accord with German practice. A subject-index of thirty-five pages makes the volume useful for general reference. A. R.

Penrose's Pictorial Annual. The Process Year Book for 1907-8, edited by William Gamble. An illustrated review of the graphic arts. 184 pages, illustrations, plates, quarto. London, A. W. Penrose & Co., Ltd. American agents, Tennant & Ward, New York. Price, cloth, $2.50.

The thirteenth annual issue of this interesting review indicates that work in the line of photo-engraving, lithography, color-printing, and related industries is still advancing.

There are included in the volume specimen illustrations of every branch of the reproductive processes, including two-, three-, and four-color prints, heliotypes, collotypes, wood cuts, and newspaper half-tones.

The text is made up of sixty-five articles, by various contributors, covering the subjects which are essential to the process worker.

R.

Hand-book of Mathematics for engineers and engineering students, by J. Claudel, from the seventh French edition. Translated and edited by Otis Allen Kenyon, New York. McGraw Publishing Co. 8-vo, cloth, 708 pages. Price, $3.50.

There are probably few actively engaged in the engineering profession who have not at some time felt the need of a reference book containing brief demonstrations of the mathematical theories involved in engineering investigations. Although general principles may be carried in mind and a required formula desired, neither the mathematical dexterity nor the time needed is always available.

Claudel's hand-book meets this condition by presenting in one volume a concise and lucid development of the mathematical processes usually employed by the engineer under the conventional headings, arithmetic, algebra, geometry (plane and solid), trigonometry (plane and spherical), analytical geometry and calculus.

The explanations, though brief, are full enough to make it valuable for systematic reading, as well as a most useful time-saving device in the drawing office or designing department of an engineering establishment.

For the latter class of users smaller type would have made it a more convenient size. L. E. P.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 4 83RD YEAR OCTOBER, 1908

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

The Telepost.

[*The Report of the Franklin Institute, Through Its Committee on Science and the Arts, on the Telepost: A New System of Automatic Telegraphy, Devised by Patrick B. Delany, of South Orange, N. J. Sub-Committee: E. Alex. Scott, Chairman; Carl Hering, Wm. O. Griggs, Richard L. Binder.*]

[No. 2427.]

The United States Patents submitted by the inventor, Patrick B. Delany, Nos, 709,752, 720,004, 720,233, 790,193, 800,364, and 802,740, describe, respectively, means for handling receiving tape; means for utilizing the static charge of the circuit; receiving tape for chemical telegraphs; transmitting and receiving apparatus; telegraphic tape recording apparatus, and an electro-magnetic perforator.

The patents cover the latest development in automatic telegraphy, the purpose of the inventor being to adapt the system to existing business conditions and to cheapen the cost of the service. The system embraces both the Electro-magnetic and Electro-chemical methods of receiving messages and transmitting them by perforated tapes.

The use of perforated tapes, or ribbons of paper, is almost as old as the art of telegraphy. Bain, a Scotchman, was the pioneer in Automatic telegraphy, especially of the chemical method. A Philadelphian, nearly ninety years ago, made the discovery that an electric current could be used to make a mark, but Bain first used the principle for recording telegraphic signals. Wheatstone, an Englishman, followed with an ink recorder, and having a better machine for punching the tapes than Bain's and with better financial support, the Wheatstone system superceded Bain's in England. In America, Bain competed with Morse in the early days of commercial telegraphy, but did not remain long in the field.

The most notable use of the chemical system was by the Automatic Telegraph Company, which built lines in 1871 from New York to Washington and Charleston, with offices at Philadelphia and other intermediate points. It continued in business for about three years with fair success, when Jay Gould obtained control of the stock and sold it to Vanderbilt and Western Union interests. Delany, Edison, Johnson and some other well known electrical engineers, were prominent in that company, Mr. Delany being its general manager. He has never wavered in his belief that automatic telegraphy must eventually become universal. One by one he has overcome the electrical and mechanical difficulties which beset the system.

In the thirty-five years which have elapsed since the extinction of the Automatic Telegraph Company, there has been no increase of speed in the hand transmission of the Morse lines. On the contrary, the operating force has become less efficient, as is shown by the statement of the president of the Western Union Telegraph Company, who fixes the average speed of transmission of messages over the lines of that company at fifteen words a minute, not more than sixty per cent. of the average in 1875.

The principal difficulty encountered by all high-speed telegraphs, and which gave the old Automatic line the most trouble, is "retardation," or the "static charge," or "capacity," of the circuit. After a signal has been sent and the circuit has been opened at the sending end, a current continues to flow from the receiving end until the accumulated static charge has run out. This additional current leaves a record on the receiving tape and makes the message illegible. As each signal is followed by this residual current, the spaces between the dots and dashes

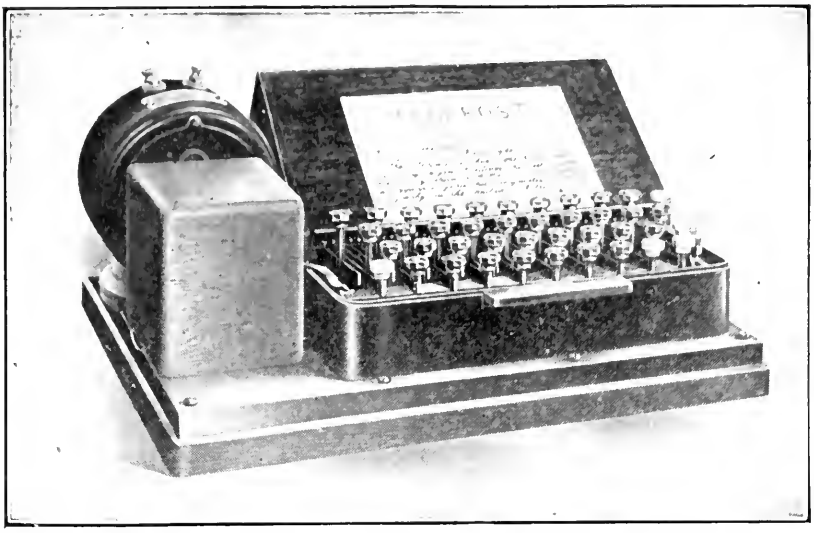
on the record are filled up, the words run together. This difficulty increases in proportion to the length of the lines, as the "capacity" is proportionate to its surface, and also to the character of the insulation covering the wire. The capacity of submarine cables is very great, and in practice the line is not fully discharged between signals, but merely varied in amount of static charge as messages are being sent.

In a former patent which came before the Institute in 1896, Mr. Delany described a method of sending dots only into the line, the dashes being received as a double line of dots, thus distinguishing them from the dots of the alphabet, which were received in a single line. This method had two advantages; first, the line received less current from the battery and the static charge was not so great as if dashes had been sent; second, the dots in the double line were readily distinguished as dashes, even though they ran together.

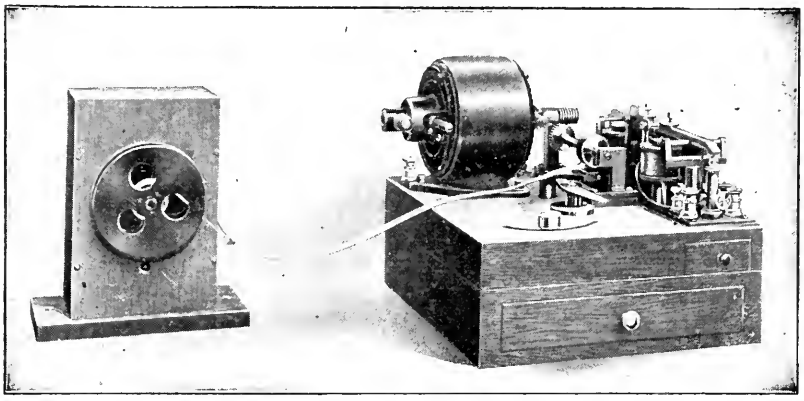
The most important of the patents submitted in the present application is United States Patent 720,004, which deals with the objectionable static charge. In this patent Mr. Delany describes a method of utilizing the "capacity" of the circuit in producing the record on the receiving tape. Dots only are sent into the line. The sending tape is so punched that immediately after the dot signal is sent, a reverse current is sent from the opposite pole of the battery, which neutralizes the static charge on the line. If, however, a dash is intended, the reverse current is not applied to the line until a sufficient interval has elapsed to permit the static charge to make a mark upon the receiving tape; the disturbing element is thus made to do work.

As the capacity of electric circuits varies with the length and size of the wire, capacity of instruments in circuits, character of insulation, and other conditions, it might happen that a circuit would have too small a capacity to produce a dash. The patent provides that in such cases capacity may be added to the desired amount by the introduction of condensers or similar means, such as a parallel circuit, so that the chemical method may be used on short as well as long lines.

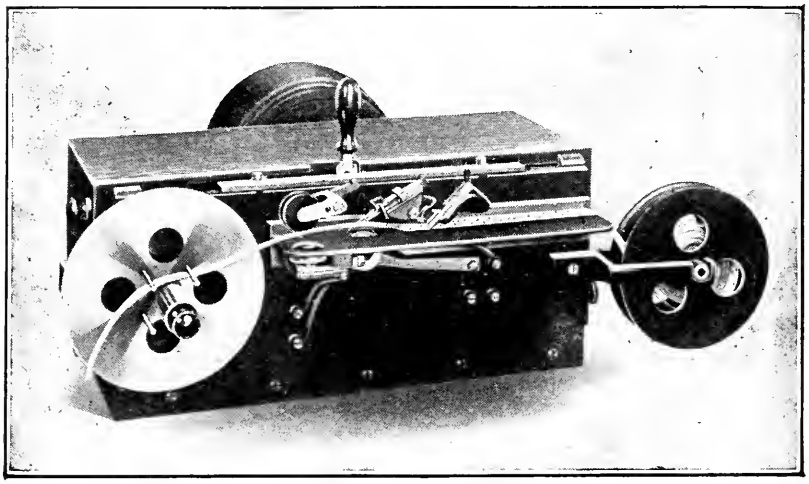
The capacity of the line as a distributing factor having been removed, it is a short step to increase the speed and distance over which chemical telegraphs may be operated. So long as any current reaches the receiving station, the tape will record it, although



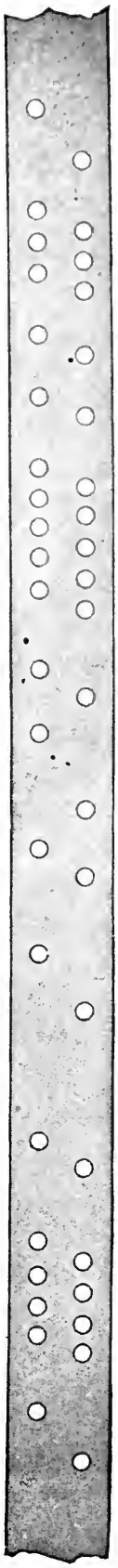
Keyboard



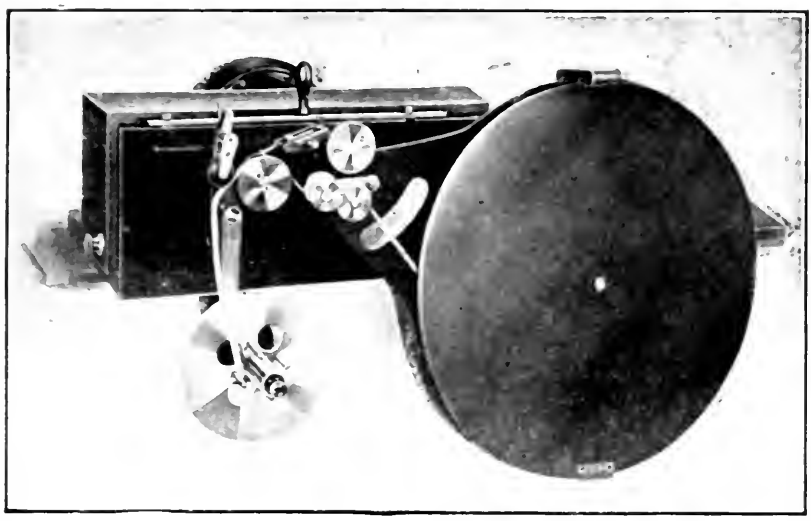
Perforator



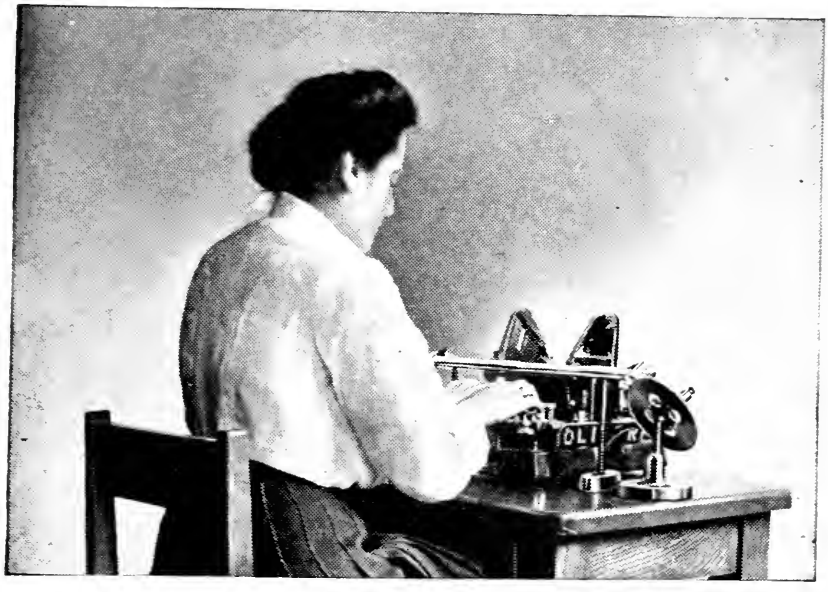
Transmitter



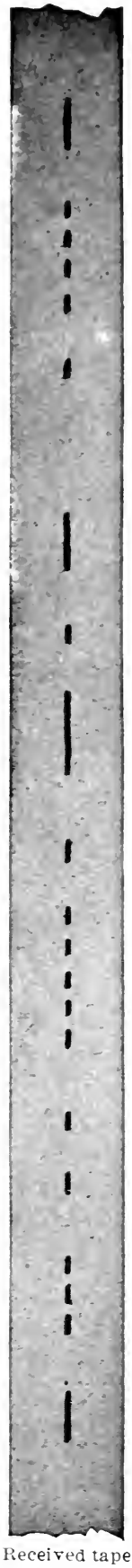
Perforated tape



Receiver



Transcriber



Received tape

with a lighter shade as the current decreases. The interruptions which interfere with the Electro-magnetic system, due to bad insulation, electric and magnetic storms, are entirely eliminated from the chemical system, which has no moving parts at the receiving end operated by the line current. It is only necessary that the circuit shall be clear enough for the operators to get intelligible Morse signals over it, to receive messages on the tape with absolute clearness.

The transmitting and receiving apparatus are described in United States Patent No. 790,193, which combines some recent improvements with prior patents to make the system more completely automatic and improve its efficiency. Among these improvements are electro-magnetic starting and stopping devices by which the movement of the transmitter may be automatically arrested, or started, by current from the distant station; or the receiving instrument at the distant station may be automatically started or stopped by current from the transmitting station. The instruments at both stations therefore start and stop simultaneously, or may be stopped at the will of the operator at either station. The running out of the transmitting tape automatically stops the receiving instrument. This feature keeps the operators in close touch with each other, and facilitates the transaction of business.

The transmitting and receiving offices are connected with each other over a circuit normally equipped with Morse instruments, and the operators communicate with each other by the Morse system. When messages are to be sent the transmitting operator places the punched tape, rolled up on a block, on a spindle, with one end of the tape between the rolls which draw it past the transmitting fingers. He then notifies the receiving operator, who places a roll of chemical tape on the receiver. By throwing one switch the Morse set of instruments is disconnected, the automatic instruments are put on the circuit, and the apparatus at both stasions is set in action. Should anything go wrong, the receiving operator can instantly stop the transmitter at the sending station.

One difficulty with receiving tapes has been that they expand when placed in the chemical solution after having been rolled up on a reel for use. This expansion tears the tape and unfits it for use. To remedy this Mr. Delany passes the tapes through crimping rolls, which corrugates them in different styles, longitudinal,

transverse, in straight or wavy lines, which permits of their being wound as firmly as may be necessary for handling without disturbing the coil, and allows for saturation by the fluid without rupturing the tape. This is covered by United States Patent No. 720,233.

United States Patents Nos. 800,364 and 802,740 cover claims for improvements in Electro-magnetic recorders and perforators for transmitting tapes, such as may be used for transmission in automatic telegraphy, or such perforations of, or record upon the tape as may be actuated from a distance through the medium of an electric circuit, and which may be used as the final record, or be used for transmitting through another circuit.

The latter of these is an improvement upon a former patent, and is designed to adapt the apparatus for use with a single polarity of current. Two polarized relays with biased armatures are used instead of a single relay with a neutral armature. One acts by the movement of its armature to open the circuits of the punch magnets; the second polarized relay controls the first. The punch magnets are alternately energized for a brief period only, while the armature of one relay is passing from its back stop to the contact which energizes the other relay. The punches therefore do not impede the movement of the tape.

This apparatus is designed particularly to be operated from a distant point. Business houses connected with the central telegraph office by wire, as many are now connected, may send their message by the Morse system and have it received as a perforated tape. This would be used in transmission over the high-speed line to destination, where it would be received chemically. Or the tape could be used in place of an operator to send the message over a branch line to a Morse operator, at a speed suited to his ability to receive it.

Where messages pass through repeating stations, they may be received on a perforated tape at a speed several times greater than by a Morse operator, and retransmitted over another circuit. This method would greatly facilitite the handling of business from branch lines and relieve the overburdened trunk lines. Press dispatches may thus be sent to local points at a very small cost, a single tape sufficing for several circuits.

In connection with this apparatus Mr. Delany has invented a key by which the Morse characters can be made at a very much

higher rate of speed than by the ordinary Morse key. The operator moves the lever horizontally to the left, closes the circuit and makes a dash. He releases it, and a vibrating arm, weighted at the end, opens and closes the circuit, making dots until the operator again moves the lever for a dash. Very rapid writing can be done in this way without fatigue.

The Committee saw the apparatus covered by these patents in operation on two occasions, and tested the speed of transmission of the chemical system at twelve hundred words a minute. The record on the tape was perfect, much more uniform than could possibly have been made by hand transmission. The same tape transmitted at a slower speed was received on the Electro-magnetic recorder as a punched tape, and to the ear of an experienced operator was perfectly clear and intelligible.

The commercial importance of Mr. Delany's completed system of high-speed automatic telegraphy, and particularly of his elimination of that bane of telegraphy, the static charge, or retardation, becomes more and more evident as its application to existing conditions is considered. High speed upon long or short lines is now assured. The carrying capacity of a line is made sixty-fold greater than hand-worked lines. Expert service is reduced to a minimum. Errors in transmission are eliminated. Line maintenance is decreased in proportion to increased speed. As a result of these conditions the cost of service can be made so low that the volume of business should be very great.

The Institute is of the opinion that the invention described in Mr. Delany's patent, United States Patent No. 720,004, in connection with the improvements covered by the other patents referred to, by which the capacity effect of the circuit is used to assist in forming the record, is worthy of the highest award, and the Elliott Cresson Gold Medal is therefore conferred upon Patrick B. Delany.

Attest: WM. H. WAHL, *Secretary.*

Philadelphia, April 1, 1908.

History, Manufacture and Analysis of Maple Products.

By Albert P. Sy, Ph.D.

Maple sirup and sugar belong to North America; they are not produced in any other country, and only in limited parts of this continent, namely in the New England and northern Middle-West States, and in Canada. We are, therefore, dealing with products whose early history must be associated with the history of the country and with the history of the original Americans, the Indians. In nearly all the earlier accounts of the Indians given to us by travellers, discoverers and adventurers, we also find accounts of maple sirup and sugar. In some cases, it is true, these accounts are by no means complete; but it must be remembered that these early writers were, as a rule, not scientists, but for the mose part missionaries or adventurers.

The question as to who discovered the sweet maple sap and the fact that sirup and sugar can be made from it has been much debated. At first thought it appears quite probable that the Indians, with their natural shrewdness would not be long in discovering maple sap; they depended largely upon the products of the forest for their food. It has been argued* that the Indians belonged to the stone age and had no metallic vessels in which to evaporate the sap to produce sirup or sugar. But these were not absolutely necessary; the sap evaporates spontaneously; sirup or sugar is found on wounded maple trees; spontaneous evaporation from wooden or bark vessels would leave sugar; freezing the sap would concentrate the sugar, and this latter fact was known to the Indians.† They also knew how to evaporate the sap in clay or bark vesesls by dropping hot stones into it.‡ Writing about the Iroquois Indians, Morgan says:§ "The Iroquois have long been in the habit of manufacturing sugar from the maple. Whether

*Morgan: League of the Iroquois, p. 187.

†Forestry Bulletin, U. S. Dept. Agr., No. 59. p. 5.

‡"Capture of John Smith," 1755-59.

§"League of the Iroquois," L. H. Morgan, p. 193.

they learned the art from us or we from them may be a difficult question; although the former would seem the more likely, from the want of suitable vessels among them for boiling." Ely,* after quoting from writings of early explorers, says: "This shows that the Indians understood and made use of the sap of different maples before the advent of Europeans; it was an established industry among them before the discovery of the Mississippi. * * * Lafitau and Bossu, writing at different periods, agree explicitly in ascribing the origin of maple sugar to the Indians." C. H. Jones† says the early Vermont settlers learned the art of maple sugar making from the Indians.

Mr. Frank H. Severance, Secretary of the Buffalo Historical Society, in a communication to the writer, says it is his "understanding that the Indians made sirup and sugar from the maple before the coming of the whites. They did not have metal vessels until they received them from Europeans. At the time of the discovery of America, the Indian was in the Stone Age. He made vessels of stone and wood, but whether these were used in boiling maple sap I cannot say. The earliest mention of the use of maple sap that I know of, speaks of it as a thing original with the Indians. I think the Europeans learned from the Indians in this matter."

Professor Cowell, Director of South Park Conservatory, Buffalo, in a letter to the writer, says: "I have heard that tale about the Indians teaching the early settlers the art of sugar making, but I have not been able to find satisfactory evidence of it. I do not believe they had conveniences for sugaring off. They undoubtedly knew that the sap is sweet, and probably they drank it in its crude state." Mr. David Boyle, of the Provincial Museum, Toronto, writes: "I have made a good deal of inquiry about the question with regard to Indian knowledge of maple sugar and sirup. I don't believe the Indians ever knew anything about maple sugar or sirup until the arrival of the French in Quebec, and it is my belief that it was taught to the Indians by a French doctor named Saussure, early in the 16th century. The Indians no doubt knew that maple sap is sweet, but beyond that, it was impossible for them to take any steps towards the manufacture of

---

*"Garden and Forest," Vol. 4, p. 207.

†"Expansion," I, 5, p. 5.

either sirup or sugar. They had no means of tapping trees, and no way of reducing the sap to any thickness."

As far as tapping is concerned, it seems to the writer that the Indians are just as likely to have used the old method of cutting gashes into the trees as the early white settlers. To reduce the sap, there are of course other methods than boiling in metal vessels. It surely does seem that the Indians must have known that maple sap on concentration yields a sugar. The writer can remember making the observation as a boy of ten years, that when hickory wood was used for camp fires, from the ends of these logs projecting from the fire there would distil the sap, the water coming off as steam, leaving a gummy mass of sugar.

T. Wheeler states* that the Indians used maple sap four thousand years ago: they caught it in troughs of wood. Many myths and legends relating to the maple tree are found among the Indians. For the Chippewas†, an Ovid-like metamorphois of Nishosha, the magician, took place, and in a few seconds he stood a tall and stiff maple tree. By some of the Indians, a certain month of the year was called the "sugar month," or "sugar moon," indicating that sugar-making was aboriginal Another evidence of antiquity of Indian sugar-making is in their ancient religious festivals instituted to the maple. One of these is the "Maple Dance,"‡ the sugar festival in the spring, when old and new sugar were mingled by the medicine man, and the aid of Great Spirit invoked.

The Ojibwa word for maple sugar is zeence-zee-bah-quod, meaning, "drawn from wood or tree;" another name is *"Enin-ah-tig Weesh-ko-bun*, which means "man, wood sugar." There are a great many Indian names for the maple tree, sugar tree, maple sugar, and sugar, but with one exception, not one of these has as yet been found which resembles or relates to any European name for sugar. In the Cree language the French white sugar is called by the special name "so-kaw," probably a corruption of the French *sucre*.

Lescarbot, a Paris lawyer, who came to New France in 1606,

---

*"Garden and Forest," Vol. 6, p. 120.

†"Garden and Forest," Vol. 4, p. 207.

‡Among the Iroquois it was called "O-ta-de-none-ne-o-Na-Wata." See Morgan "League of the Iroquois," p. 187.

writes* about the Indians: "S' ils sont pressez de soif ils ont l' industrie de succer les arbres, d'ou distille une douce et forte agréable liqueur, comme je l' ai experimenté quelque fois." Lescarbot here undoubtedly refers to maple sap, for he describes† "erables" (Acer rubrum). Pierre Boucher (1663) describes the maple‡ and says, "quand on entaille ces Herables au Printemps el en degoutte une quantité d' eau, qui est plus douce que de l' eau detrempée dans du sucre." Robert Boyle, in 1663, wrote: "There is in some parts of New England a kind of tree whose juice that weeps out of its incisions, if it be permitted slowly to exhale away the excess moisture, congeals into a sweet substance."

Père Christien Le Clercq, a missionary (1675) writes:§ "Dans le temps que les arbres étoient en sève quelqu' un de nous se trouvait indisposè, ou ressentoit quelque debilité de coeur nous faisons une fente dans l'ecorce d'un erable qui distilloit une eau sucree qu'on amassoit avec un plat d'ecorce, et qu'on beauvait comme une remede souverain."

He also states,¶ "Par une ouverture assez petit, qu'on fait avec la hache dans érable, on en fait distillé des six ou douze pots Ce qui m'a paru essez remarquable dans l'eau d'érable, c'est que si à force de la faire bouillir on la reduit au tiers, elle devient un veritable syrop, qui se durcit à peu prés comme le sucre, et prend une couleur rougeâtre. On en forme des petits pains q'on envoie en France par vareté, et qui dans l'usage sert bien souvent au defaut dû sucre Francais." He states explicitly that they made sugar by boiling the sap. Unfortunately he does not mention the kind of vessels used.

Joutel (1684), a companion of LaSalle, writes:** "La Providence nous fournissoit une espèce de manne pour adjouter à notre bled d'Inde, laquelle manne estoit d'un suc que les arbres jettent dans cette saison et notamment les erables." He then describes in detail the tapping of trees and collecting of sap, and says, "laquelle etant bouillie, à force de diminuer devient du sucre.

---

*Lescarbot, Vol. 4, p. 865; see also "Garden and Forest, 4, p. 171.

†Lescarbot, Vol. 3, p. 852.

‡"Historie Veritable et Naturalle de la Nouvelle France," p. 44.

§"Establissment de la Foy," Vol. 1, p. 252.

¶LeClercq: Nouvelle Relation de la Gaspesie, p. 124.

**Voyage depuis les Illinois jusque à Missilimakinak, p. 509.

Nous nous servions de cette eau pour fair bouillir notre bled d'Inde ou 'sagimité,' ce qui lui donnait un assez bon goust c'est à dire un peu sucré. Il semble que la Providence fournit à tout ces comme il n'y a point de cannes à sucre dans ces cantons les arbres en fournissent, du moires j' en ai veu qui estoient excellent."

La Hontan (1684)* describes the tapping of trees and collection of sap. He says: "On fait de cette sêve du sucre et du sirop si precieux qu'on n'a jamais trouvé de reméde plus propre à fortifier la poitrine."

Père S. Rasles (S. J.), in 1689 wrote:† "Les femmes s' occupent à la recevoir dans des vases l'ecorce, lorsque ces arbres la distillent; elles la font bouillir, et elles trient un assez bon sucre. Le premier qui se tire est toujours le plus beau."

L. Hennepin‡ (1698) speaks of the maple sap and its use as a drink; also that they boiled it and obtained a reddish sort of sugar, much better than ordinary cane sugar.

In the writings of Père Lafitau (1700) we find the following§ description of the Indians making sugar from maple sap: "Elles font ensuite bouillir cette eau sur le feu qui en consume tout le phlegme, et qui epaisset le reste en consistence de syrop, ou même de pain de sucre, selon le degré et la quantite de chaleur qu'ils veulent lui donner." (See Plate I.) He also says that the French work it better than the savages, *from whom they have learned to make it.* He says that the sugar almost always has a little burnt taste. Ely¶ explains this burnt taste by saying that it would naturally result from the primitive Indian method of evaporating sap by dropping red-hot stones into the sap contained in bark or wooden vessels. Pinkerton** gives a full account of maple trees, maple sirup and sugar among the North American Indians.

In 1756, the Indians were using brass kettles for evaporating maple sap. James Smith, an English boy of eighteen, who was

---

*LaHontan, Vol. 2, p. 61.

†Rasles "Letters Edifiantes," Vol. 4, p. 83.

‡"New Discovery," Pt. II, p. 147.

§"Moeurs des Sauvages Ameriquains," II, p. 83.

LaBeau, in "Adventures de C. Le Beau, Tome 1, p. 45, uses the identical words, having evidently copied them from Lafitau.

¶"Garden and Forest," 4, p. 183.

**Voyages and Travels in All Parts of the World," Vol. 13, p. 359.

captured and adopted by the Indians, writing of his experiences,* describes in detail how the Indians made sirup and sugar by evaporating maple sap in two brass kettles holding fifteen gallons each. He says that they commonly used this sugar by putting it into bears' fat until the fat was almost as sweet as the sugar itself, and into this mixture they dipped their roasted venison.† Smith re-

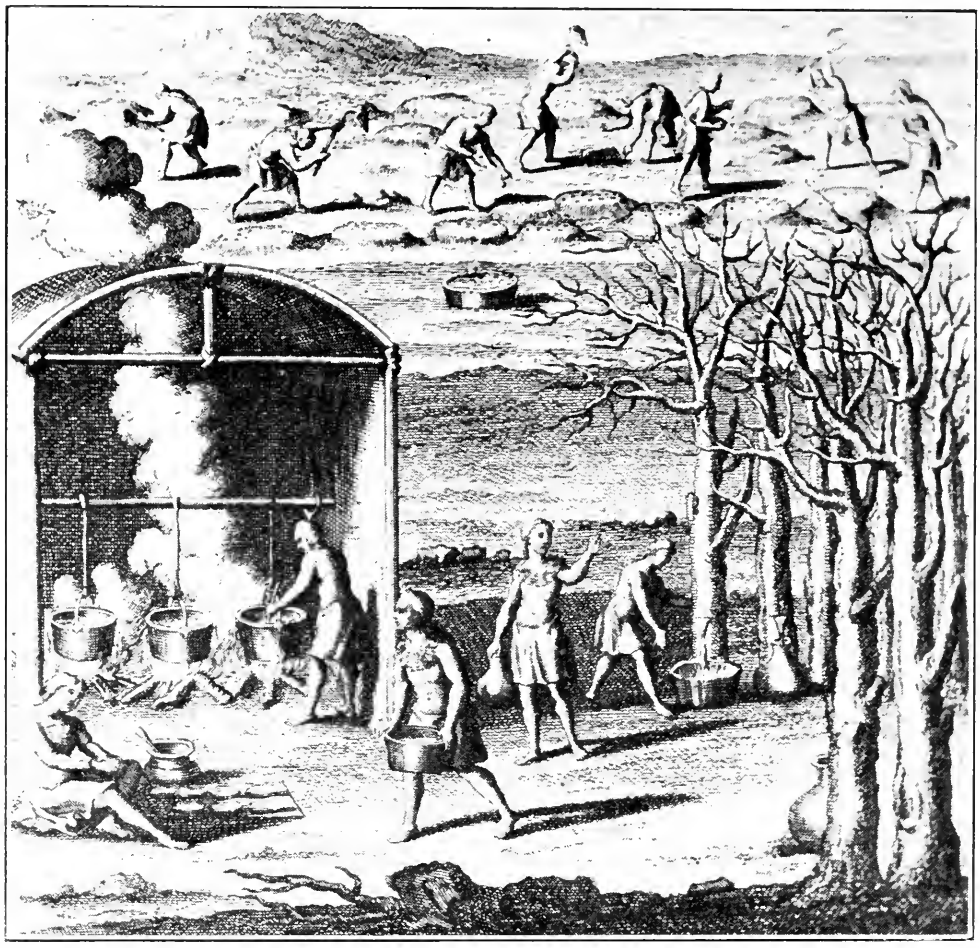


Plate 1. Indians tapping trees and evaporating sap making maple sugar. From Lafitau, II p. 154 (about 1700 A. D.)

lates‡ that in 1757 they had no kettles with them, and they concentrated the sap by allowing it to freeze and throwing away the ice. After several freezings the water remaining in the vessels changed color, became brown and very sweet.

---

*Captivity of James Smith." p. 36.

†This shows that even the savages knew something about a balanced diet. This mixture furnished fat carbohydrates and protein.

‡Ibid. p. 68.

M. Bossu, a captain in the French navy writing* about the Indians (1756) collecting sap, says: "Qu ils font bouillir jusqu' à ce qu' il soit réduit en sirop lequel étant rebouilli, se convertit en sucre un peu roux, et semblable à la manne de calabre. Lez Francois, etablis aus Illinoiz, *out appris des suavages la façon d' en faire.*" In his "Nouveaux Voyages dans l'Amerique Septrentionale," p. 237, Bossu describes a beverage which the Indians made from green corn by expressing the juice, and then adding maple sugar. This they used as a tonic. The white women used it for washing their faces, for their complexion. Mention is made of maple sugar by Carver,† Henry,‡ Lancourt;§ and nearly all travelers in North America during the 18th century mention maple sugar.

One of the earliest and most complete descriptions of the maple industry is one by Dr. Rush.¶ He mentions the fact that Mr. Jefferson, afterward President, never used any other than maple sugar on his table. Dr. Rush thought that eventually we would produce enough maple sugar so as not to need any cane sugar, made by slaves in the West Indies. He says: "A material part of the general happiness which Heaven seems to have prepared for mankind will be derived from the manufacture and general use of maple sugar. I cannot help contemplating a maple sugar tree without a species of veneration, for I behold in it a happy means of rendering commerce and slavery of African brethren in sugar islands as unnecessary."

Early in the 19th century, the maple industry was described by Père Sagard,** and N. Denys.††

BOTANY AND GEOGRAPHY OF THE MAPLE.

Considerable confusion exists with reference to the classification of the different species of the genus *Acer*. Linné named the

*"Nouveaux Voyages aux Indes Occidentales." Part I, Lettre 9, p. 164.

†"Travels Through Interior of North America, 1766."

‡"Travels and Adventures in Canada and Indian Territories." 1760.

§"Travels Through U. S. of N. Am."

¶Trans. American Philosophical Soc., 1792.

**"The Grande Voyange du Pays des Hurons," p. 102.

††"Historie Naturalle de Peuples, Animaux, Arbres et Plantes de l' Amerique Septentrionale." 2, p. 316.

silver or soft maple *A. saccharinum;* this was the species with which he was most familiar (the hard maple does not grow in Europe, except very rarely) and as its sap is as sweet as that of our hard maple, he called it *saccharinum.* Confusion of species names was started by Wangenheim in 1787, by calling the sugar or hard maple *A. saccharinum*, thinking that Linné meant the sugar maple by this name. Botanists who to-day follow Wangenheim's classification use the name *A. dasycarpum* for the soft or silver maple, due to Errhart (1789). In 1785, Marshall called the sugar maple *A. saccharum*, and the silver maple *A. glaucum;* since Marshall's *A. glucum* is older than Ehrhart's *A. dasycarpum*, the former should be used if Linné's A. saccharinum is discarded.

The correct classification, as adopted by careful writers and botanists to-day,* is *Acer saccharum,* hard, rock or sugar maple; *Acer saccharinum,* soft or silver maple; *Acer rubrum,* red maple.

All the species of *Acer* have sweet sap, and while the hard maple furnishes by far the largest part of maple sugar, the sap from the other species is also occasionally used, especially the soft or silver maple. The sugar maple is a stately forest tree; it usually produces a great many seeds, which are ripe in the fall of the year; these seeds germinate and grow readily, even in very shady places, producing after a while a very dense growth. If left to itself, this would never be very productive for sugar making, and a dense young grove must be thinned out.† The maple is an excellent tree for decorative effect; it has a beautiful shape and is a good shade tree in summer. In autumn the beautiful landscapes seen in some parts of the country are due to the brilliant leaf colors of the maple. These colors are due to the disintegration of chlorophyll and the presence of xanthophyll and erythrophyll; sugar maple leaves in autumn range in color from orange, gold, crimson to scarlet.

For sugar making, the range of the maple is limited to the New England States, New York, Pennsylvania, Ohio, Lake States, and Southeastern Canada (St. Lawrence and Lake regions). It does not flourish in the Old World and is rarely found there.

---

*"Maple Sugar Industry," W. F. Fox, Bulletin 59, Bur. Forestry, U. S. Dept. Agr. Also private communication from Prof. Cowell.

†Bulletin 59, Bur. Forestry, U. S. Dept. Agr., p. 29.

STATE	1850	1860		1870		1880		1890		1900	
	Sugar lbs.	Sugar lbs.	Sirup gals.	Sugar lbs.	Sirup gals.	Sugar lbs.	Sirup gals.	Sugar lbs.	Sirup gals.	Sugar lbs.	Sirup gals.
Vermont....	6,349,357	9,897,781	16,253	8,894,302	12,023	11,261,077	128,091	14,123,921	218,252	4,779,870	160,9
N. Hamp...	1,298,863	2,255,012	43,833	1,800,704	16,884	2,731,945	79,712	2,124,515	81,997	441,870	41,58
Mass.....	795,525	1,006,078	15,307	399,800	2,326	878,793	13,017	558,674	33,632	192,990	27,17
Maine.....	93,542	306,742	32,679	160,805	28,470	153,334	82,006	84,537	71,818	5,500	16,024
Conn	50,796	44,259	2,277	14,266	168	44,092	2,173	8,617	1,437	4,930	948
New York..	10,357,484	10,816,419	131,843	6,692,040	46,048	10,693,619	266,390	10,485,623	457,658	3,623,540	413,159
Penn	2,326,525	2,767,335	114,310	1,545,917	39,385	2,866,010	14,067	1,651,163	154,650	1,429,540	160,297
W. Va.....	.....	.....	.....	490,606	20,209	310,866	28,696	177,724	19,032	141,550	14,874
Maryland..	47,740	63,281	2,404	70,464	374	176,076	2,043	156,284	10,21	264,160	5,825
Virginia.....	1,227,665	938,103	99,605	245,093	11,400	85,693	7,518	26,991	3,468	19,310	1,677
N. Jersey...	2,197	3,455	8,088	419	5	2,496	334	210	134	.....	.....
Ohio..	4,588,209	3,345,508	370,512	3,469,128	352,612	2,895,782	495,839	1,575,562	727,142	613,990	923,519
Indiana	2,921,192	1,541,761	292,908	1,332,332	227,880	235,117	242,084	67,329	180,702	51,900	179,576
Michigan...	2,439,794	4,051,822	78,998	1,781,855	23,637	3,423,149	131,990	1,641,402	197,775	302,715	82,997
Missouri....	178,910	142,028	18,289	116,980	16,317	58,964	16,224	20,182	8,333	12,055	5,474
Illinois.....	248,904	134,195	20,048	136,873	10,378	80,193	40,077	13,260	13,978	4,090	9,357
Wisconsin..	610,976	1,584,451	83,118	507,192	31,218	488,837	58,012	128,410	48,006	4,180	6,625
Minn.....	2,950	370,669	23,038	210,467	12,722	76,972	11,407	34,917	12,091	29,580	1,079
Iowa.....	78,407	315,436	11,405	146,490	9,315	50,710	17,766	45,120	14,413	2,320	2,662
Tenn.....	158,557	115,620	74,372	134,968	4,843	31,296	3,688	9,167	1,186	1,160	171
Arkansas...	9,330	3,077	124	1,185	75	.....	.....	335	.....	.....	.....
N. Carolina	27,932	30,845	17,759	21,257	418	4,103	582	7,713	1,142	1,180	129
Georgia	50	991	20	.....	.....	.....	.....	.....	.....	.....	.....
Miss.....	.....	99	.....	125	.....	.....	.....	.....	.....	.....	.....
S. Carolina	200	205	.....	2	.....	.....	.....	.....	.....	.....	.....
Kentucky..	437,405	380,941	140,076	269,416	49,073	66,535	27,530	11,259	10,468	2,340	2,367
Alabama ...	643	228	.....	.....	3	.....	.....	.....	.....	.....	.....
Louisiana ..	255	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Texas	.....	.....	.....	.....	5,032	.....	.....	.....	.....	.....	.....
Total	34,253,436	40,120,205	1,597,589	28,443,645	921,057	3,6576,061	1,796,048	32,952,927	2,258,376	11,928,770	2,056,611

The geographical distribution of the sugar maple can best be understood by reference to the table opposite page 257, taken from the U. S. Census Report, and is also shown by the maps on Plate 2,

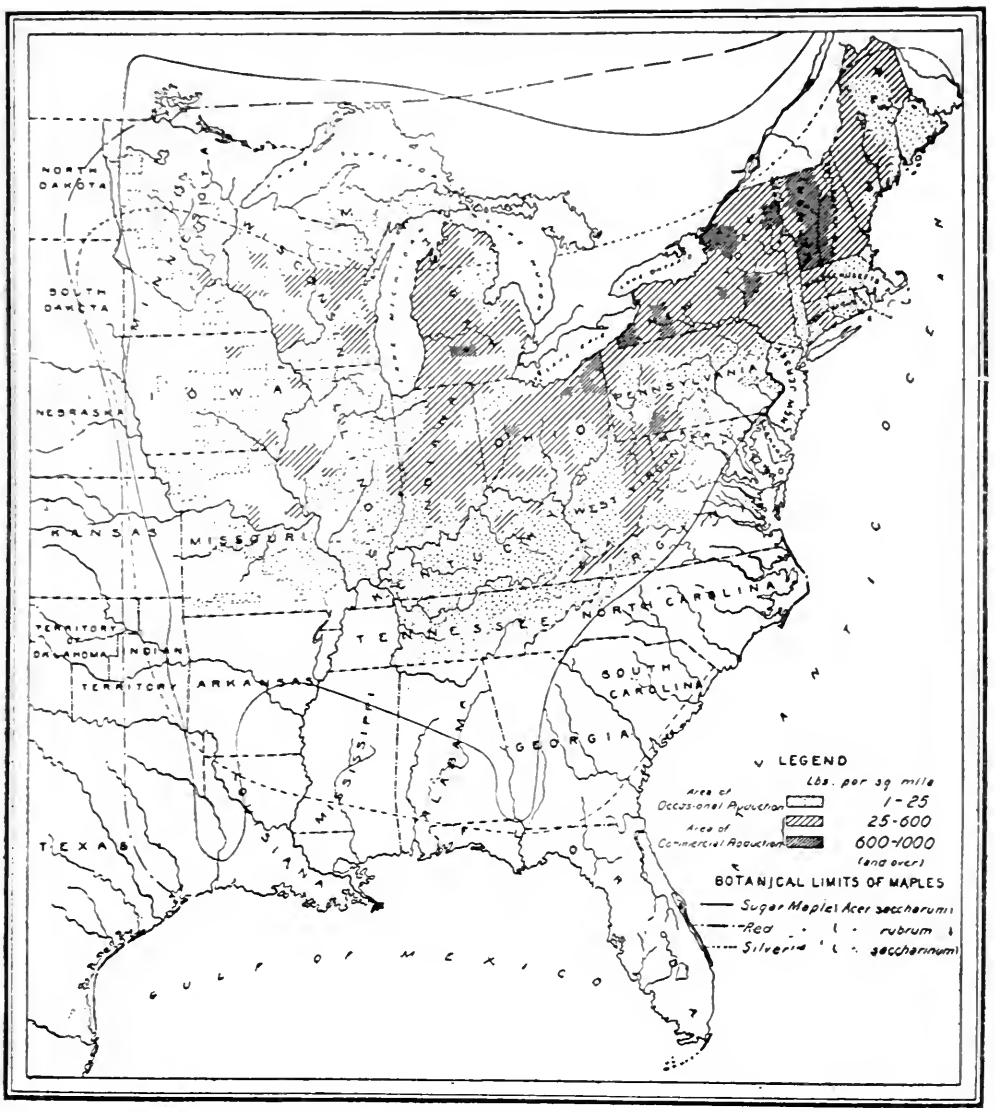


Plate 2. Fig. 1. The field of maple sugar production in 1880.

taken from Bulletin 59, Bur. Forestry, U. S. Department of Agriculture, by permisison.

A better idea of the relative rank of the States producing maple sugar can be obtained from Plate 3, compiled* from census

*Bulletin 59, Bur. Forestry, p. 15.

records for the years 1850 to 1900. About 1860 the maple sugar industry was at its height, the State of New York producing more than any other State, over 10,000,000 pounds of sugar and 131,000 gallons of sirup. The great falling off in 1900 for the entire country was due to several causes, principally because 1899 was a

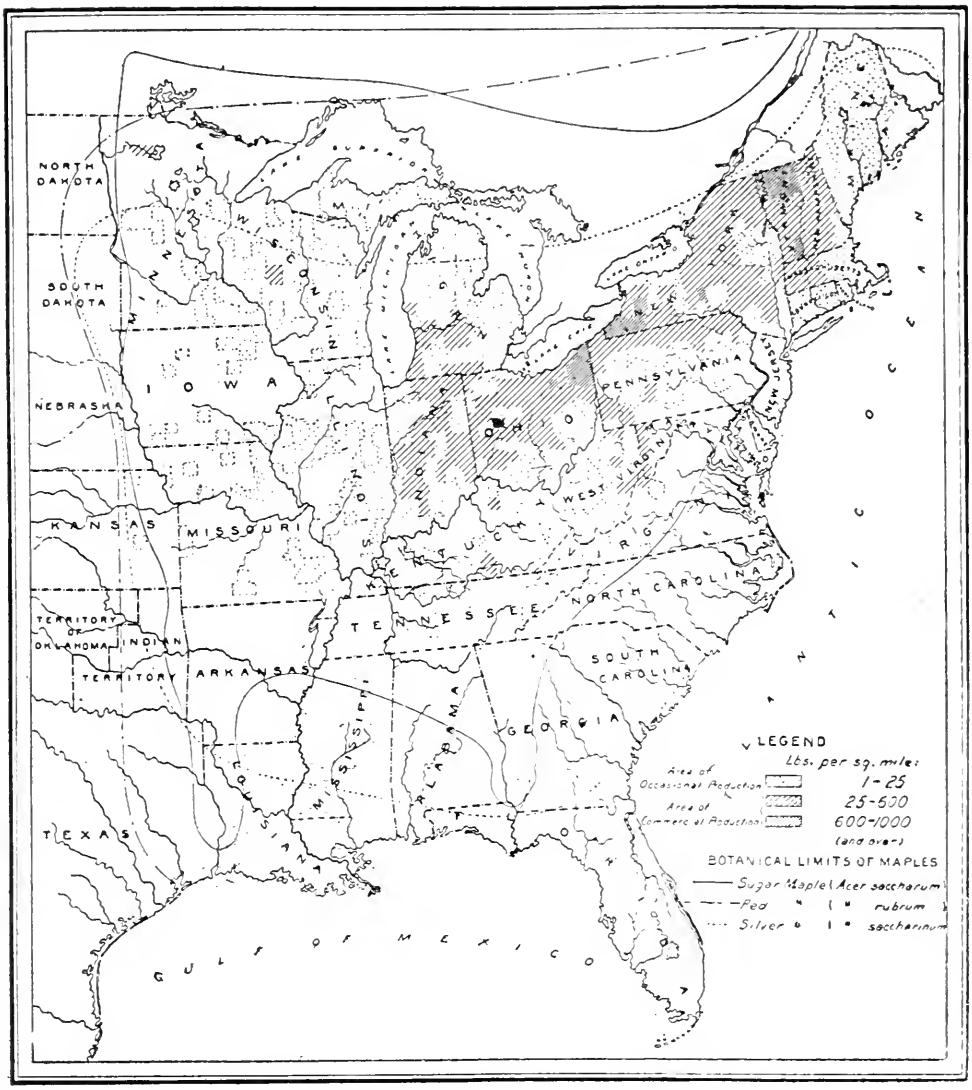


Plate 2. Fig. 2. The field of maple sugar production in 1900.

very poor season, and in some other States, especially Vermont, the "maple worm" did great damage. In Illinois, Indiana and Michigan the decrease is accounted for by heavy lumbering. This the writer found is also true of western New York; the sugar bushes in the neighborhood of Chaffee and Arcade being

rapidly sold and cut down for making shoe lasts. The maple furnishes a splendid hard wood which is used for many purposes; it is excellent for furniture making, is one of the best woods for making hardwood floors, and is used for almost anything requir-

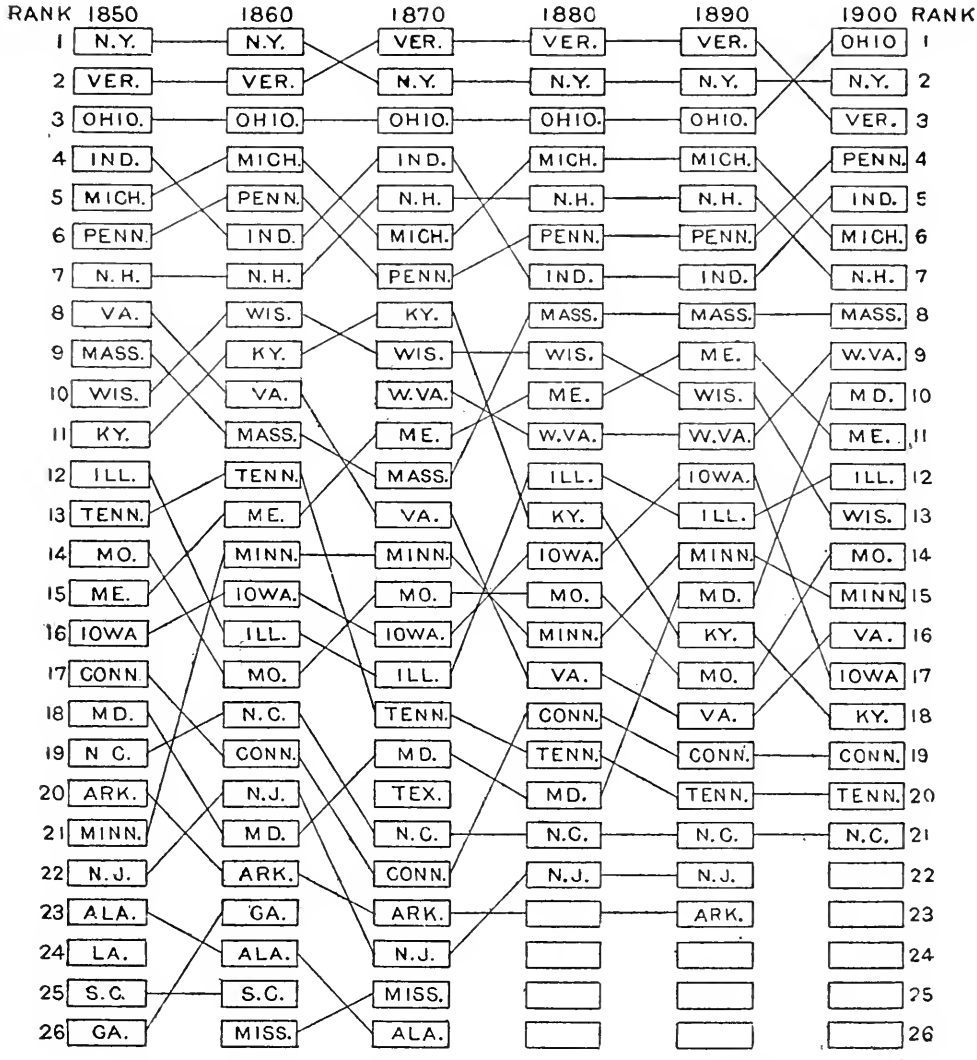


Plate 3. Showing rank of states producing maple sugar from 1850 to 1900.

ing a hard wood, such as shoe lasts, shoe pegs, tooth picks, chopping bowls, saddle trees, turnery, ship keels and shoes, etc. The sugar maple sometimes grows full of small knotty spots, and lumber made from it has an unusually pretty appearance, and is used in furniture making for making "birds-eye" furniture. Ac-

cording to reports from the Bureau of Forestry, in 1906 nearly one billion board feet of maple lumber were produced. Western New York farmers claim that it is much more profitable for them to sell lumber than to make sugar. This is probably true, considering only a few years' production, but does not apply for the entire life of a maple bush.

PHYSIOLOGY OF THE MAPLE.

The sap in plants corresponds to the blood in animals; it distributes in the plants the food materials necessary for growth. The assimilative processes in plants generally are well understood and need but little brief mention here. The principal food of plants is carbon dioxide which, under the influence of sun-light, the green tissues of the plant decompose, oxygen being given off. The chief result of this decomposition of CO_2 is the formation of a carbohydrate in the plant cells which contain chlorophyll. The first visible product of assimilation is starch,* $(C_6H_{10}O_5)n$; it is of course understood that there are intermediate products, that is, between the CO_2 and the starch. This starch becomes in reality, the food of the plant. It is decomposed and energy set free. This energy is manifested as energy of motion; Goodale† believes that movements of liquids in the plant are due to this energy.

During the season of growth there is produced and stored in the maple tree starch; this is converted into cane sugar, $C_{12}H_{22}O_{11}$, and the latter into invert sugar (dextrose and levulose), which botanists erroneously call "glucose." It is to be noticed that cane sugar or sucrose is not used by the growing leaves or buds, but that it must first be changed into a simple sugar. The starch, a polyose, is changed to sucrose (cane sugar) a diose, and this in turn into invert sugar, which is a mixture of two simple sugars or monoses. This process of inversion begins early in the spring of the year when the tree starts

*First shown in 1862 by Sachs, "Botanische Zeitung," 1862.

†Goodale: Physiological Botany, p. 322.

to grow. The amount of sucrose circulating in the tree will depend principally upon the amount of starch stored during the preceding summer* or season of growth, and this amount of starch in turn depends upon conditions of sun-light and leaf development. Exhaustive experiments made at the Vermont Experiment Station show† that sugar content varied with the amount of leaf surface. Careful measurements and calculations showed that a certain tree in 1899 had a leaf surface of about 9000 square feet; in 1900 this same tree had about 15,000 square feet; this increase was not due to increase in size of the tree, but to the fact that in 1899 the tree was beginning to recover from the effects of an attack of caterpillars, while in 1900 it had almost completely recovered. During these same years, the experimental orchard, the trees of which were in a similar condition, produced sap which in 1899 had an average sugar content of 3.13%, while in 1900 it rose to 3.41%. Isolated trees exposed to a maximum amount of sun-light yield sap which usually contains from 1.5% to 2.0% more sugar. While the carbohydrates stored in the maple consist principally of starch, yet there are undoubtedly others present, either originally formed at the same time when the starch is formed, or the decomposition products of the starch. Stover‡ does not believe that there is enough starch formed and stored in the maple tree to account for all the sugar and the physiological work exhibited in the spring; he believes that mannan also is produced and stored as reserve food. His experiments proved that mannan is present in the sugar maple. Since mannan will readily hydrolyze to mannose, he thought that the latter might be found in the sirup and sugar made from the maple sap. Careful tests however showed no trace of mannose.

It has been shown by microchemical tests that as the starch disappears from the tissues of the sap wood, the content of succrose and invert sugar (called glucose by botanists) increases. A maple branch cut in midwinter and kept for some time in a warm

---

*The Indians knew what kind of a sugar season to expect; they said that if the maple leaves ripen and turn yellow, and the buds perfect themselves so that the leaves fall off naturally without a frost, then there will be a good flow of sap the following season; if the leaves fall prematurely and the buds are not perfected, then there will be a poor yield of sap.

†Vermont Station, Bul. 103, p. 55.

‡F. N. Stover: Bul. Bussey Inst., 1902, p. 34.

room soon changes its starch to sucrose and invert sugar. It is now generally believed that these changes are due to the activities of the protoplasm and brought about by chemical ferments or enzymes secreted by the living cell.

The change from sucrose to invert sugar must take place principally in or near the leaves and buds, since but a very small percentage of invert sugar is found in the sap; at least this is the case at the beginning of the season. As will be seen from the results of analyses of a number of maple products by the writer, there is always present some reducing sugar (invert sugar). It is known, of course, that some of the sucrose becomes invert sugar on account of being heated during the evaporation of the sap, or by fermentation and microorganisms before and after evaporation. Early investigators did not find invert sugar in maple sap, and all invert sugar was supposed to be formed during evaporation. Results obtained by the writer as to reducing sugar in different sirups and sugars indicate that a difference in the process of preparation could not account for the wide ranges, and that there must be corresponding differences in the original sap. Other investigators have noticed this, and it is now generally known that sirup made from first runs of sap (early in the season) is low in reducing sugar, while that made from late runs produces a dark product with larger amounts of invert sugar. Analyses of fresh saps, early in the season, made by the writer, are as follows:

	Reducing sugars.	Total sugars.
Acer saccharum	0.029%	3.46%
Acer saccharinum	0.020%	3.20%

These results show that reducing sugars do occur in the sap, and sirup and sugar made from such sap would contain about 0.50% reducing sugars even if none are formed during or after evaporation of the sap.

It might be supposed that invert sugar in maple sap is formed from sucrose by the malic acid also present, but if this were the case, then, since all genuine maple products contain malic acid, we would expect considerable, and about the same amount, in the different sirups or sugars. Fruit acids cause but very little hydrolysis of cane sugar. Invert sugar occurs in some ripe fruits, but Buignet has shown that it is formed by the action of a ferment and not by a fruit acid.

Maple sap is essentially a dilute solution of sucrose, and contains traces of reducing sugars (invert sugar), organic acids, chiefly malic, mineral matter (inorganic salts) and small amounts of protein substances. As might be expected, the composition of the sap varies greatly; it may be different for different trees and also vary for the same tree at different times during the season and with conditions of weather and sun-light. An average of a great many analyses of sap shows the sucrose content to be about 3%. Many trees yield sap containing less than 3% of sucrose, and some trees give a much higher sucrose figure. Wiley* reports a tree producing a sap containing 9.88% and another containing 10.20% of sucrose; but in nearly all cases where the percentage of sucrose is higher, the quantity of sap is small. The average sucrose for the season for the tree last mentioned was 5.01%.

The average yield of sugar per tree for a season is about three pounds; many trees do not produce this amount, and others greatly exceed this. Jones† reports measurements and calculations of a certain small maple tree showing that it contained about 120 gallons of sap at the opening and 150 gallons at the close of the sugar season. A tree containing 150 gallons of sap would carry about thirty-seven pounds of sugar, taking 3% as the sugar content of the sap. Such a tree if it yields three pounds of sugar, would give up only about 8% of its total sugar. Larger trees, producing about three pounds of sugar, would yield probably not more than 4% of its total sugar. With 3% sugar, it would require about seventeen quarts or thirty-four pounds of sap to produce one pound of sugar; the pails usually used for collecting sap will hold a little over four gallons, and the farmer expects a pound of sugar from a pail full of sap. A fair average daily flow of sap is about five quarts or ten pounds, and about twelve gallons for the season. Jones reports‡ a tree which produced 11.95 pounds of sugar in one season; Dr. Rush§ in his remarkably complete description of the maple sugar industry in 1792 mentions that a Mr. Low, of Montgomery County, New

*Bul. 5, p. 209, Chem. Div. U. S. Dept. Agr.
†Vermont Station, Bul. 103, p. 139
‡Vermont Station, Bul. 103, p. 134
§Trans. Am. Philos. Soc., 1792.

York, made twenty pounds and one ounce of sugar from one tree, the sap running from April 15 to 23, 1789; this tree yielded twenty-three gallons of sap on the first day.

The quantity* of invert sugar in maple sap is usually recorded as "a trace;" Morse† reports a tree yielding a sap with an average of .0075%, and another tree with .0123% of invert sugar. In the sap used in the laboratory for making pure sirups, the writer found the following percentages of reducing sugars: hard maple sap, 0.029%, soft maple sap, 0.020%.‡

Of the organic acids in maple sap, only the malic acid has received attention. This exists both free and combined; Wiley§ made determinations of the free acid by titrating the fresh sap with n/100 soda; the maximum amount of acidity, calculated to malic acid, was 0.005%, and was as low as 0.0005%. That this does not represent all the malic acid present is shown by the fact that a genuine sirup, containing 66% of sucrose, shows about 0.5% of total malic acid, while if the original sap contained only 0.005%, the sirup made from it would contain only 0.11% malic acid. A 65% sucrose and 0.5% malic acid content in a sirup is produced from a sap containing about 0.023% total malic acid.

The principal inorganic elements in maple sap are potassium, calcium, sodium, magnesium and iron in the order named. It appears impossible to determine the combinations in which these elements exist in the sap; change of combinations would occur during evaporation, and on ignition of sirup or sugar for ash determination, the organic acid radicals would change to carbonate. For the composition of ash obtained from maple sap, Wiley¶ gives the following data, calculated to percentage on original sap:

K_2O	CaO	MgO	Na_2O	Fe_2O_3	P_2O_5
.0314%	.0207%	.0061%	.0013%	.00066%	.00596%

These figures represent an average of four analyses of sap from the same tree on different days, the tree being tapped about three feet from the ground. Further information is given under "ash," where in addition to these data, the quantities of manganese,

*Wiley: Bul. 5, Chem. Div. U. S. Dept. Agr., p. 193.

†N. H. Station Bulletin.

‡The amount of reducing sugars and solids not sugar increases toward the end of the sap season. See Ver. Bul. 26, p. 40.

§Bul. 5, p. 210, Chem. Div. U. S. Dept. Agr.

¶Bul. 5, p. 193, Chem. Div. U. S. Dept. Agr.

CO_2 So_3 and Cl are reported. The total ash obtained from sap is relatively considerably greater than found in sirup or sugar, because ash is lost during evaporation by skimming, clarifying and straining, and settling out of calcium malate.

Maple sap contains small quantities of protein substances. Wiley* reports an average of .019% in the sap of four trees. The average from a grove of 700 trees was .0088%, and from another of 1500 trees it was .0103%.†

In this connection there should be mentioned what is known among the farmers as "niter" or "sugar sand." This is a sand-like, gritty substance which is deposited during the process of evaporation of the sap; this deposition does not begin until the sap has been concentrated to a thin syrup of about eight pounds per gallon. This "niter" is removed from all good maple products by either allowing the sirup to settle or straining it through felt or other material; this should be done also if the sirup is to be concentrated for making sugar, otherwise the sugar will be gritty. "Niter" is found in all pure maple products, varying, however, from small amounts to large quantities, depending upon method of preparation and character of the soil upon which the maple trees grow; it has been stated that trees on lime soil produce more "niter" than others.

But few analyses if "niter" are reported; the following is taken from the Indiana Station Report for 1899:

Water	6.11%
Insoluble matter	9.13%
Reducing sugars	12.74%
Sucrose	26.88%
Calcium	12.89%
Malic acid	20.86%
Potassium	0.72%
Protein	0.40%
Magnesium	trace

This evidently is an analysis of "niter" which still contains considerable sugar or sirup; part of the sucrose is probably present as

*Ibid. p. 210.

†During evaporation of sap the protein substances are partly coagulated and skimmed off. For amounts left in the finished products see Hortvet, Report Minn. State Dairy and Food Commissioner, p. 455 (10th An. Report).

calcium sucrate. It is usually stated that "niter" is mainly calcium malate; it has been stated* that "niter" is principally calcium tartrate; some still believe that it is a mixture of calcium malate and calcium tartrate.

The question as to the cause of pressure and flow of sap in plants has been the subject of many researches, especially by botanists; but in spite of this, there still exists a great difference of opinions as to the explanation of these phenomena. It will not be necessary to discuss this subject, except with reference to the maple. Perhaps the best summary of theories as to the cause of sap flow is that given by L. R. Jones:†

(1) High water content of the tree. This does not explain the flow of sap, since the tree contains more water several weeks after flow ceases than it does during flow.

(2) Root pressure. Exhaustive experiments made by the workers at the Vermont Experiment Station‡ show that there is very rarely any root pressure.

(3) Alternate freezing and thawing. This was a popular theory twenty-five years ago, but does not hold good, since the wood of the maple tree seldom freezes.§

(4) Physical expansion due to rise and fall of temperature. If this theory were correct, the rate of sap flow should be proportional to rise in temperature, which is not the case in practice. In the experiments made at the Vermont Station there was observed in a maple tree trunk a change in pressure from five pounds suction per square inch to a pressure of twenty-five pounds within a few hours; it does not seem likely that this phenomenon can be explained by expansion of gas or other substances in the maple trunk.

(5) Jones believes¶ that the flow of sap in the maple is due to activity of living cells under certain stimuli or conditions. The principal stimulus is undoubtedly the more or less sudden fluctuation of temperature from slightly below 0° to slightly above 0°. This is in accord with the fact that during the sap season the sap

*Vermont Station Report, 1872, p. 222.

†Paper read before Vermont Sugar Makers' Association, kindly loaned to the writer before publication.

‡See Bul. 103, Ver. Ex. Sta.

§See Bul. 103, Ver. Ex. Sta.

¶See also "Experiment Station Record" 17, p. 123.

flows best on bright days preceded by nights during which there was freezing.

The rate at which the sap flows in a maple has been determined by Jones and Orton,* who found that the rate when the sap is flowing in the direction of the grain of the wood toward the tap hole or orifice, is from two to six inches per minute. C. H. Jones, *et al.*, have made the maple sap flow the subject of exhaustive study,† and almost all phases of this subject were fully studied and reported. By inserting pressure gauges into different parts of a tree and making observations of temperature, etc., many interesting results were obtained. By using self-recording gauges and thermometers continuous records were obtained. Two of these are shown in Plates 4 and 5.‡ Plate 4 shows that during that experiment the temperature changed frequently from above to below 0° (32°F.) and that there were, parallel with these changes, fluctuations in pressure; when the temperature remained stationary, the pressure was also stationary *near 0°;* suction results when the temperature falls below 0° (32°F.). Plate 5 shows temperature changes nearly all above 0°; under these circumstances, even though the temperature variations are considerable, the pressure changes are but very slight, and always near 0°. In two instances, the plate shows, the temperature went below 0° and immediately the pressure changes became much greater. The plate also shows that "outer pressure" (depth two inches) and "inner pressure" (five inches) do not differ materially, and that temperature alone is not responsible for these changes.

MANUFACTURE OF MAPLE PRODUCTS.

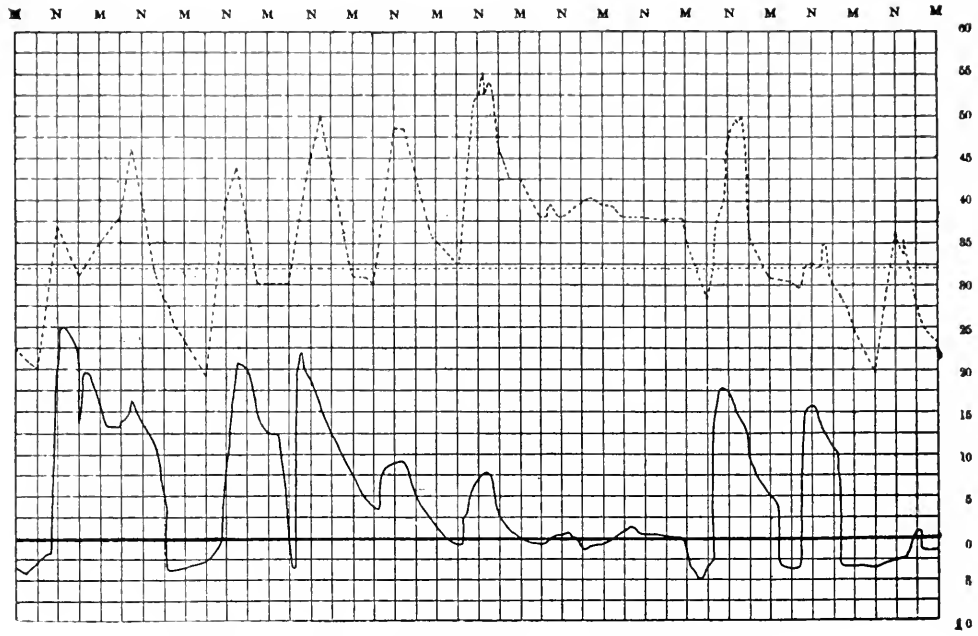
It is not intended to give a detailed technical description of maple sirup and sugar making. However, since the most important part of this paper is to deal with the analysis of maple products, a short description of the process of manufacture seems necessary for a better undesrtanding of the analytical data

As stated before, maple sap may be considered a dilute (3%) solution of sucrose (cane sugar) with small amounts of other or-

*Bul. 103 Ver. Ex. Sta., p. 106.

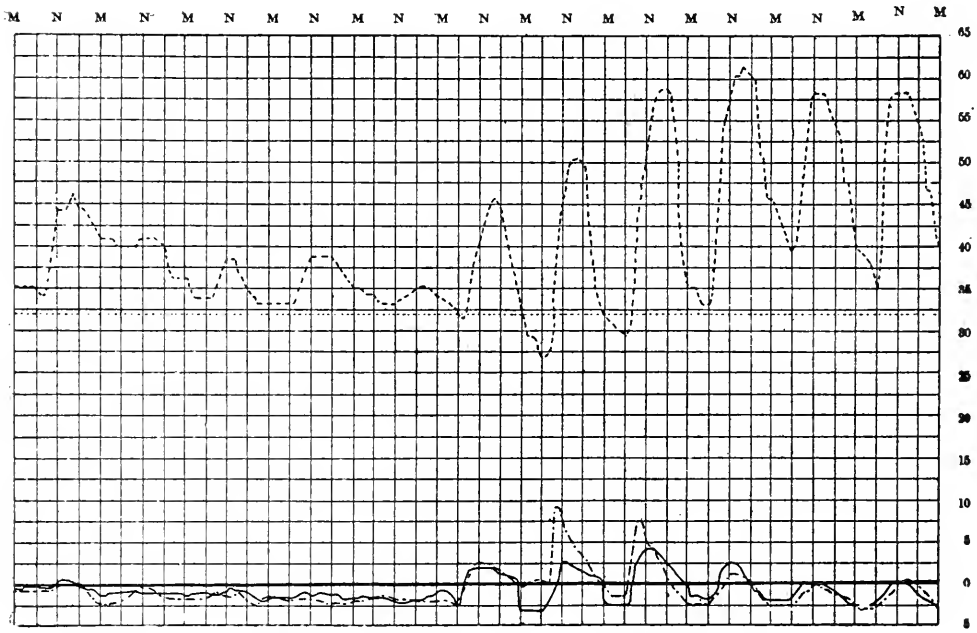
†Bul. 103, "The Maple Sap Flow," Ver. Ex. Sta.

‡By permission from Bul. 103, Ver. Ex. Sta.



M midnight; N noon; ——, pressure in pounds; - -.- -, temperature in ° F.

Plate 4. Showing relation between temperature and sap pressure.



M midnight; N noon; ——, inner - . - , outer pressure in pounds; - - - temperature in ° F.

Plate 5. Showing relation between temperature and sap pressure.

ganic and inorganic substances. That the sap contains sugar must have been known long before any sirup or sugar was made from it. It would naturally suggest itself that the sugar might be obtained by evaporating the water from it. Two natural processes acocmplish this; first, freezing, and second, spontaneous evaporation. Both were known to the North American Indians, also to our early settlers. One of the earliest artificial processes of evaporation was that of Indians who heated stones red hot and placed them into vessels containing sap. This of course was necessary as long as they had no metallic vessels; these vessels were one of the first things they obtained by trade from early settlers, and they soon used them for evaporating sap for making sirup and sugar. An interesting illustration is shown in Plate 1, the original of which is in "Lafitau, Moeurs des Sauvages Ameriquains," Vol. II, p. 154 (about 1700), and shows the manufacture of maple products in all its stages, as Lafitau saw it among the Indians.

The primitive kettle process is still in use to-day, due to the fact that maple products are made by a great many small producers, much in the same manner as cane sirup for home consumption in Central Illinois and other places. Plate 6* shows this method as practiced in Canada to-day. Plate 7† shows a different arrangement of the kettles, permitting their removal from the fire for taking out the sirup. Plate 9 (writer's photograph) shows evaporators used in Pennsylvania. Although pans are used, the process is essentially the primitive kettle process, in which sap is boiled sometimes all day, fresh sap being added continually, the sirup being removed at night. This long boiling produces a very dark product, containing more reducing sugars and impurities than the product from modern evaporators. This dark colored product is still preferred by some, since it has a very strong flavor.

The larger producers of maple products use more modern apparatus, called evaporators. With this form of apparatus the process is continuous, the sap flowing in at one end while the sirup is drawn off at the other. This of course produces a much lighter colored product than long boiling. A form of direct heating

---

*From Buffalo "Courier."

†Vermont Station Report.

Plate 6. Open kettle evaporation as practiced in Canada.

Plate 7. Open kettle evaporation. Kettles can be swung from fire.

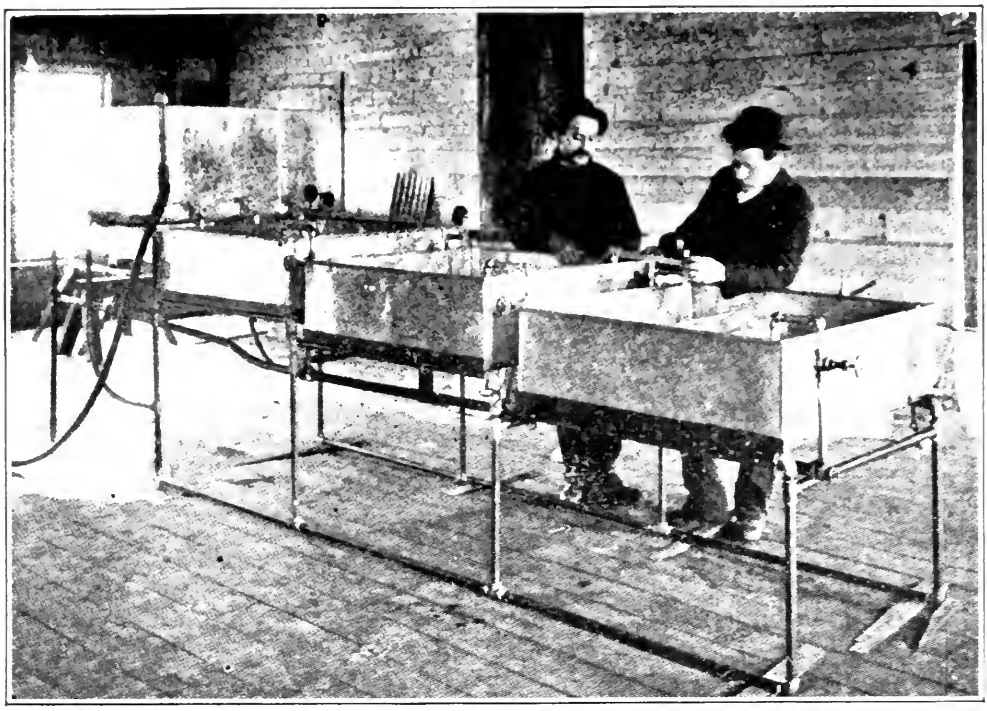


Plate 8. A modern steam-heated evaporator.

Plate 9. Open air, flat kettle, direct fire evaporator in Pennsylvania.

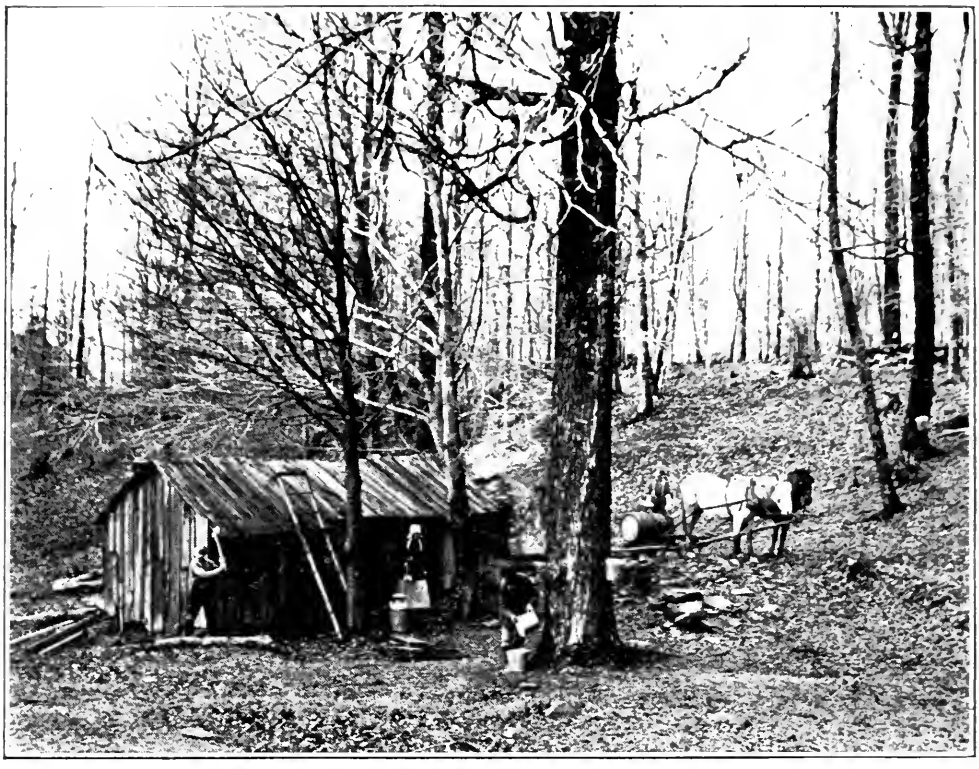


Plate 10. New York maple sugar camp. (Author's photo.)

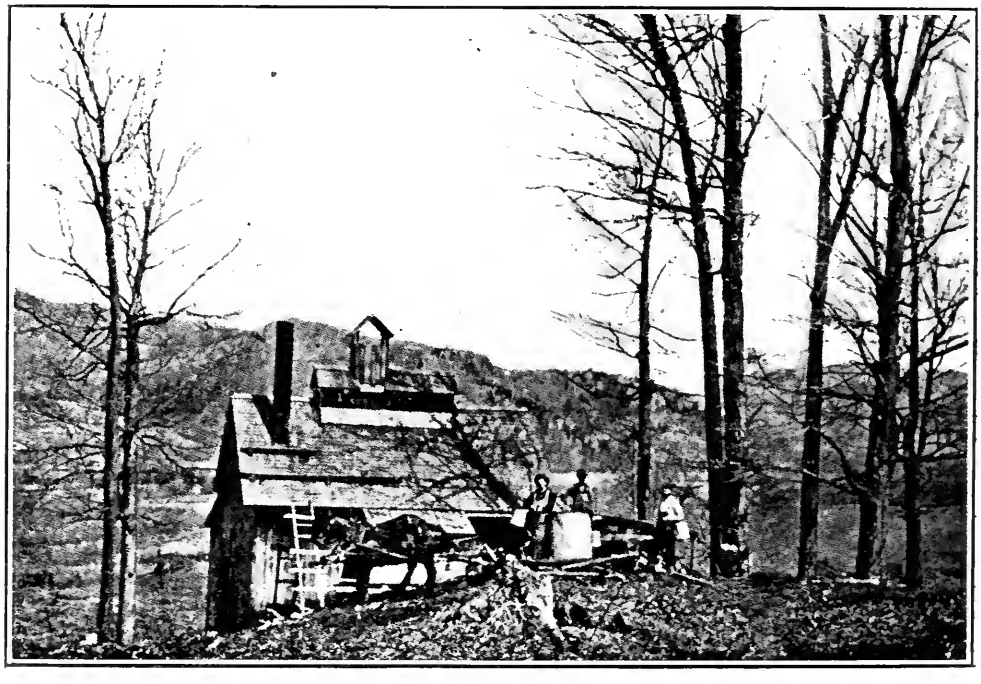


Plate 11. Typical Vermont maple camp. (From Vermont Station Report.)

evaporator is shown in Plate 12*, and Plate 8† shows a steam heated evaporator. Before evaporating, the sap is strained; it should be collected and evaporated at least daily, since it readily ferments or "sours," unless the most scrupulous cleanliness is observed. The writer has been unable to find any statements as the kind of fermentation and nature of products formed. Sap collected by the writer when allowed to "spoil" acquired a strong

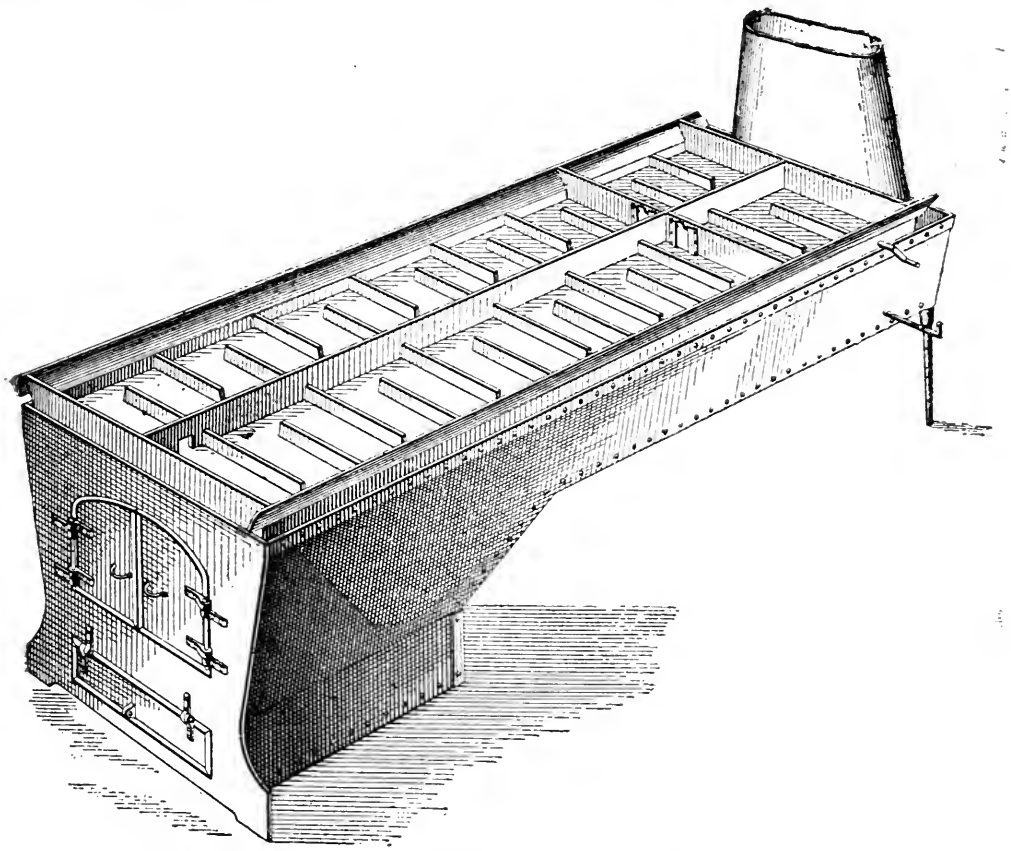


Plate 12. Modern, direct heating, continuous process evaporator,

odor of lactic acid, and the term "souring" seems quite appropriate.

For making sirup, the sap is boiled until it has a specific gravity of 1.325; at this density it boils at 219°F. and the sirup weighs eleven pounds to the gallon. This is the standard for sirup; if boiling is stopped before this point is reached, the sirup will be thin and more liable to ferment; if the density is greater than 1.325 sugar will separate (crystallize) from the sirup. Modern

*From Bul 59, Bur. of Forestry.

†Vermont Station Bulletin.

evaporators use a hydrometer or thermometer and produce a uniform product. Others guess at it, or take out a little from time to time and allow it to cool.

The various sap conditions have already been mentioned. During the evaporation, the proteids are coagulated, rise to the top and are partly removed, together with other substances, by "skimming." As the sap becomes more concentrated, the "niter" becomes more insoluble and is deposited.

If sirup only is to be made, evaporation is stopped at 1.325 sp. gr., the sirup allowed to cool, strained (to remove "niter," etc.), and put in cans. To make sugar, the evaporation may be continued until it boils at 233°F.; in case the "niter" is not removed, the temperature must be up to 235°F.; the sirup is then placed into moulds where it solidifies on cooling. This produces an inferior sugar, since it contains the "niter," and a better and more usual plan is to make sirup and draw off, allow to cool and settle, strain and continue the concentration. By the small producer this process, called "sugaring off," is usually done at home* (See Plate 13) while the preliminary evaporation is done in the "sugar bush."*

STATISTICS

While maple sirup and sugar are well known all over the United States, yet the importance and magnitude of the industry are hardly ever mentioned or understood, except in the New England and Lake States and adjoining Canada. In the State of Vermont it is a very important industry, and the name "Vermont" and maple products are closely associated, frequently, as will be seen later, illegally. The distribution and density of maple sugar production for the year 1880 and 1900 in shown in Plate 2.† The table on page 259 shows the sirup and sugar production of the different States since 1850, and the relative rank of each State is shown in Plate 3‡ By act of Congress of October 1, 1890, there was provided a bounty on sugars made in the United States. The

*Detailed descriptions of the modern methods for sirup and sugar manufacture can be found in Bul. 59, Bureau of Forestry, and the Reports and Bulletins of the Vermont Agr. Ex. Station.

†From Bul. 59, Bureau of Forestry

‡From Bul. 59, Bureau of Forestry, p. 15.

act provided that after July 1st, 1891, and until July 1st, 1895, a bounty be paid on sugars made either from beet, sorghum, cane or maple, two cents per pound on sugars testing 90% or over by the polariscope, and $1\frac{3}{4}$ cents per pound on sugars testing less than 90% but more than 80%. The effect of this bounty was not as expected, more farmers preferring to make sirup instead of sugar, and others did not take advantage of it on account of the formalities and requirements involved.

Plate 13. Straining and "sugaring off" at home.

ANALYSIS OF MAPLE PRODUCTS.

Until now, maple products have always been found in the markets grossly adulterated. Not many years ago, it was almost impossible to get a pure sirup or sugar. The reasons for this extensive adulteration were the high price of maple products and the inability of the chemists to detect adulteration. This will be more fully discussed later under "adulteration." Even to-day, many chemists are unable to differentiate between pure and adulterated products. Important contributions to the literature on analysis of maple products have been made by Jones* and

*17th Annual Report, Vt. Ag. Ex. Sta., p. 446; also 18th Annual Report, Vt. Ag. Ex. Sta., p. 315.

Hortvet;* a great deal of analytical work is also reported by the chemists of the Canadian Inland Revenue Department. Considerable analytical and research work (as yet unpublished) has been done by Prof. H. M. Hill, University of Buffalo. Some of his work will be mentioned later, by permission.

In the following there are given all the important determinations made in the analysis of maple products.

COLOR.

Maple sugar is not refined like granulated sugar; it corresponds to that kind of crude cane sugar called "concrete." Since maple sugar is identical with sucrose, it follows that on refining it, it would lose its color and become white. The writer has a sample of maple sugar made in the laboratory by evaporating sap very slowly in a porcelain vessel; on recrystallizing this it became almost as white as granulated sugar. Maple products vary in color from a very light brown to almost brownish black.† This variation is due to two causes, principally: first, stage of the sap season, *i. e.*, whether at beginning or end of season; second, method of manufacture. Near the end of the sap season, especially if the buds have started, the sirup and sugar are quite dark in color; this is due to the fact that at this time the sap contains increasing amounts of reducing sugars and solids not sugar, and these caramelize or burn much easier than cane sugar. It is also believed that the character of the soil influences the color of the maple products.

The method of evaporating the sap has considerable influence on color. The old kettle method where some of the sap was boiled all day resulted in a very dark colored product, due principally to the formation of caramel. To determine if the presence of "niter" accelerates the formation of caramel (from invert sugar which the "niter" might produce from sucrose) the writer made duplicate dilute solutions of cane sugar and evaporated them in glass, adding a little "niter" to one sample. After several days boiling, the syrups were still almost equally colorless.

---

*Jour. Am. Ch. Soc., 26, p. 1523.

†The color of the maple product, therefore, has no relation to purity of the product.

Commercial maple products are always manufactured in metallic vessels; experimental samples made by the writer, using glass or porcelain, always resulted in light colored products. Metal transmits the heat much more readily and is therefore more apt to "scorch" the product.

Maple products usually show a reaction for tannin when tested with $Fe\,Cl_3$. Some of this tannin undoubtedly reacts with traces of iron from the vessels used and this darkens the product. According to Faradiss* caramel contains humic acid, formic acid, and other bodies; these acids would attack iron, and the resulting salts would readily react with tannin.

The color or appearance of a maple product may also be influenced by small sugar crystals (in sirup, when evaporated too far), malates or "niter," and carbonates, in suspension; phosphates, organisms and fermentation. To determine what proportion of color is due to caramel, the writer tested a number of samples with amyl alcohol. This does not discolor caramel, and if the color is due to caramel, the layer of amyl alcohol should remain colorless. Upon testing a large number of samples in this manner it was found that all pure products contain enough coloring matter other than caramel to give a distinct color to amyl alcohol. This fact was made use of in the *"color test,"* to be described later.

COLOR AND AROMA.

It is these that give to maple products their value. The flavor cannot be described but must be learned by experience; it is very pleasant and is characteristic. Experts who have tested a great many products can often detect adulterations without a chemical analysis. While the maple flavor is not equally strong in products from various parts of the country, yet dilution with cane sugar, sugar-house sirup, glucose, etc., always reduces the strength of the flavor, and often also imparts a special flavor to it, according to the adulterant used. The writer has examined a great many samples from each of the principal maple districts and has noticed a great difference in flavor. Maple sirup and sugar produced in Pennsylvania and Ohio often have but little maple

*Zeit. f. Untersuchung Nahr. Genussmittel. Vol. 2. p. 881.

flavor; one might say they taste "flat;" usually, the less maple flavor, the more a product will taste like ordinary cane sugar sirup or sugar. Products coming from Vermont and New York have a much stronger maple flavor; it is, however, not too strong and might be described as "delicate;" these products are preferred over all others by most consumers. The strongest flavor is found in the Canadian products;* all the darkest samples analyzed by the writer came from Canada.† People used to Ohio products do not care for the strong flavor found in the Canadian products; the latter remind one of the old-fashioned open-kettle-method product; the flavor is very strong in this maple, sometimes has what one writer calls a "woody" character. It appears from what has just been said that climate has an influence on flavor; the colder the more maple flavor develops. This may be due to the fact that in colder climates the buds do not start as soon as in warmer ones.

Imitation maple products, those containing very little or no real maple, always have a flavor which can most always be distinguished from the pure product. The writer has found fenugrek, vanilla, prune juice, resinless guaiacum (tr) in samples of sirup. A pure maple sirup sometimes develops a most disagreeable odor and flavor, resembling such as are produced by putrefaction of the proteins. Out of about sixty sirups the writer found three with such odor and flavor, and in these cases were caused no doubt by decomposing egg albumen or milk or cream, these being used in the manufacture to clear the product and also to prevent boiling over.

In a few instances the writer has also noticed an odor resembling hot glue; this was especially noticable in a sirup made by the writer from the sap of soft maple (A. saccharinum). This odor is probably due to the nitrogenous matter present; such a sample after it has begun to ferment, develops an exceedingly objectionable odor and taste.

A test for the odor of products under examination is as follows:‡

---

*It is well known that the strong flavor and color of the Canadian products are much used by mixers; by adding a little of this to cane sugar sirup one obtains a very good imitation maple sirup.

†One sample now on hand nearly black.

‡Jones: 18th An. Rept. Ver. Station, p. 335.

About 20 g. of sirup or sugar are weighed into a 4 oz. beaker, dissolve in from 20 to 40 c.c. of hot water, place on asbestos board and boil; the amount of water added is such as to cause the sirup to boil at 215°F. Boil gently for a few minutes, stir gently, and note odor. In making this test the writer has found it necessary always to remove the beaker from the flame and asbestos, as these interfere seriously with the sense of smell. The true maple odor is always obtained from pure products under these conditions; the odor is characteristic, and must be learned by experience with pure products.

As far as known to the writer there is no record of research on the aromatic constituents of maple products. It has been stated* that the maple flavoring is probably an ether (ester?) or aldehyde possessing a high boiling point. It is further stated that these flavoring substances are partly volatile at temperatures reached during the evaporation of sap, for there is always the well known aromatic odor in the vicinity of a sugar camp in operation. However, the really volatile part is probably exceedingly small, and the writer believes that the odor so prominent during sap evaporation is due mostly to fine particles of sap or sirup thrown into the air during the boiling or carried with the steam, much in the same manner as salt is found in sea air, or caustic soda in the air over a vessel in which a solution of the caustic has just been made.

The following experiment was made by the writer in an attempt to isolate, if posisble, the flavoring matter. Pure, fresh maple sap was boiled in a large glass flask (A) connected by a glass condenser with another flask (B); this second flask had a reflux condenser (C), the latter being connected at the top with another vertical condenser, the bottom of which reached into a small flask (E) containing water. (See Plate 14.) Six liters of fresh maple sap were placed in A, the apparatus connected and the sap boiled until it had about the consistency of sirup; the distillate in B had the characteristic maple odor, except that it was not as pleasant and not nearly as strong as maple sirup; the odor resembled that of corn cobs, or, as described by an asisstant, that of pop-corn. It suggested to the writer the odor noticed when a strong solution of glycerin is boiled; on boiling some of the lat-

*Wiley, Bul. 59, Bureau of Forestry, p. 47.

ter and comparing odors it was found that they seem to be identical. The flavor of the contents of flask B was not sufficiently marked to be compared with anything. This shows that but very little of the flavoring substances in maple sap is volatile. Nothing came over into flask E and the water in the flask acquired no odor or flavor of any kind. This again shows that the flavoring substances are not very volatile, or are at least easily condensed and held in water (in B). In order to isolate, if possible, the

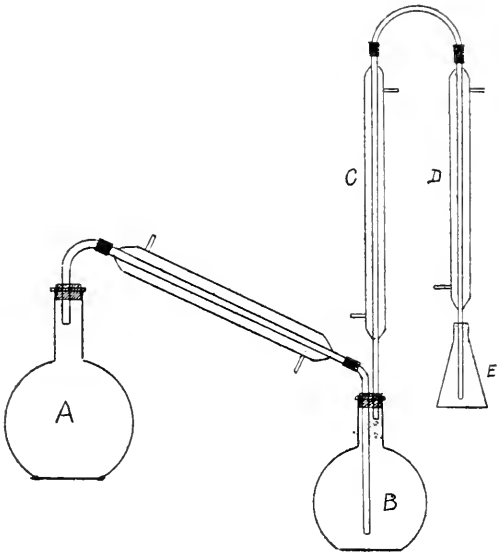


Plate 14

flavoring substance in B, the contents were transferred to a separatory funnel and extracted with ether and the latter allowed to evaporate spontaneously; from about 5500 c.c. of distillate there was obtained only a trace of residue after evaporation of the ether; this residue had the same odor as described before. It appears from this that if the flavoring substances are ether or aldehydes, they are present in but very small amounts or are but very little volatile. The writer hopes to continue experiments on this line next year, using a considerably larger amount of sap, also using different methods of separating the flavoring substances both from the distillate and the remaining sirup.

(*To be continued*)

Section of Physics and Chemistry.

Quantitative Separation of Tin from Manganese, Iron and Chromium by Electrolysis.

By M. N. Puschin.

(From "Journal de la Société Physico-Chemique Russe," XXXVIII, 764.)
Translated from "Moniteur Scientifique," XXII, I. 262, April, 1908, by
W. J. Williams, F. I. C.

There has been given in one of the preceding memoirs* a process for the quantitative separation of tin from nickel and cobalt, based on the property of these latter of not separating from solutions acidified with oxalic acid.

A priori it seems probable that iron, as the third metal of the iron group, as well as manganese and chromium, very close in the system to the three preceding metals, would not separate from solutions acidified with oxalic acid, and would thus permit their quantitative isolation from tin.

These suppositions were completely realized as far as regards iron and manganese, and partially in regard to iron granting the property of the latter of forming oxalates of the protoxides as well as of the oxides.

SEPARATION OF TIN FROM COMBINATIONS OF THE PROTOXIDES OF IRON AND OF MANGANESE.

The oxalates of the protoxides of iron and of manganese are completely analogous to those of nickel and cobalt; they are difficultly soluble in solutions acidified with oxalic acid; they give precipitates of a bright yellow color for iron and whitish for manganese, if the solution is heated nearly to boiling. Like

*Journal de la Société Physico-Chemique Russe, XXXVII, 828.

nickel and cobalt, neither the iron nor the manganese will be separated by the current from a solution in equilibrium with these precipitates. This is shown by the following experiment: To 25 c.c. of a solution of iron sulphate or manganese sulphate, containing about 0.5 gram of iron or of manganese, are added 25 c.c. of an acid solution of ammonium oxalate (saturated at room temperature) and 100 c.c. of a similarly saturated solution of oxalic acid; on heating the liquid nearly to boiling, it gave a precipitate of oxalate of protoxide of iron or of manganese. After the solution has been allowed to stand a while, the liquid is submitted to electrolysis, at the room temperature. Here are the results tabulated:

TABLE I.

Experiment.	Weight of the Cathode before experiment.	Tension of the Electrodes.	Density of the Current per square decimeter.	Duration of the Experiment.	Weight of Cathode after experiment.
With manganese—					
	13.1764	3.2 volts	2.5 amperes	2 hrs. 35 min.	13.1764
	13.1764	4.2 "	4.0 "	1 " 25 "	13.1764
With iron—					
	13.4234	3.2 "	4.5 "	2 " 50 "	13.4234
	12.4234(?)	3.5 to 4.2 "	4.0 "	1 " 48 "	13.4234

It follows from the above table, that under the conditions therein indicated, the current will separate neither iron nor manganese from the solution. Since it is easy to separate tin quantitavely from acid solutions of binoxalate by ammonia binoxalate (Klassen's method), it is clear that it is also easy to separate tin quantitatively in this way from manganese and from iron where these exist in the solution as salts of protoxides.

However, it must be observed that in analyses iron is more frequently found in combinations of the oxide than of the protoxide; since the combinations of protoxide easily change to combinations of oxide, without introducing any new metal, such as bromine for example. That is why in studying the method of the electrolytic separation of tin from iron, the combinations (or salts) of iron oxide should be especially considered. The same is true in a certain degree for manganese. But it is much more difficult to separate tin from the salts of iron oxide.

The binoxalates of iron (or of manganese) and of ammonium, differing from the salts of the protoxides, dissolve in a solution of oxalic acid; on the other hand, the salt of ferric oxide, under the influence of the cathode current, easily decomposes into a salt of

the protoxide, which being insoluble in oxalic acid, precipitates in part at the bottom of the cell and in part envelopes the cathode, thus preventing the regular precipitation of the tin. The different attempts made to find a means of solving this difficulty have not hitherto given any satisfactory results; therefore the problem of the separation of tin from iron can be considered as only half solved, especially in respect to iron protoxide.

SEPARATION OF TIN FROM COMPOUNDS OF MANGANESE OXIDE.

The question of the separation of tin from compounds of manganese oxide presents a more favorable aspect. In the presence of a sufficient quantity of oxalic acid, if the tension does not exceed 3 volts, under the experimental conditions indicated above, and the density of the current is not too great, the manganese is not deposited on the cathode, neither as metal nor as an insoluble oxalate of the protoxide, so its complete separation from tin is possible. This follows from the following experiments:

TABLE II.

	Experiments.	Quantity taken for analyses.	Tension at the electrodes. Volts.	Density of current per sq. decimeter. Amperes.	Result.	Per ct
1	Tin (Sn)	0.4269 gr.	2.2 to 2.6	0.8 to 1.0	Sn 0.4260	98.79
	Manganese (Mn)	0.5 gr.				
2	Tin (Sn)	0.4634 gr.	2.2 to 2.9	0.8 to 1.0	Sn 0.4623	99.76
	Manganese (Mn)	0.5 gr.				
3	Tin (Sn)	0.5253 gr.	2.2 to 2.8	0.8 to 2.0	Sn 0.5244	99.83
	Manganese (Mn)	0.7630 gr.				
4	Tin (Sn)	1.0761 gr.	2.2 to 2.9	1.5 to 3.0	Sn 1.0760	99.99
	Manganese (Mn)	0.5 gr.				

From the above table it is evident that the method given for the electrolytic separation of tin from manganese gives perfectly satisfactory results. It must be particularly noticed that when half way through the electrolysis it is desirable to add 5 to 10 grams of oxalic acid, that the solution may remain sufficiently acid. Then, as has been said above, the tension of the electrodes must not be increased above 3 volts, or, under these conditions, traces of manganese may be deposited. The density of the current should not be too great; for example, it should not exceed 3 to 4 amperes to the square decimeter, for the too rapid disengagement of hydrogen at the cathode can cause (though only to a small extent) the reduction of the salt of manganese oxide to an insoluble salt of protoxide, which is assuredly not to be desired.

SEPARATION OF TIN FROM CHROMIUM.

The separation of these two metals is the easiest and the most complete of all. The chromium is not deposited by the current in a solution acidified with oxalic acid. Experiments prove it.

About 5 grams chromium were dissolved in a mixture of hydrochloric acid and bromine. As in the preceding experiments the solution was neutralized with ammonia, and 25 c.c. of a solution of ammonium oxalate, saturated at room temperature, and 100 c.c. of a similar solution of oxalic acid were added, after which the liquid was electrolyzed:

TABLE III.

Weight of Cathode before experiment.	Tension of electrodes.	Density of Current per square decimeter.	Duration of experiment.	Weight of Cathode after experiment.
13.6609 gm.	2.9 to 4 volts	4.8 to 5.6 amperes	1 hr. 20 min.	13.6609 gm.
13.6609 gm.	5 "	9.2 "	2 " 25 "	13.6606 gm.

These two experiments show clearly that the chromium does not separate from the solution under these conditions. Accordingly about 0.5 gm. tin and approximately as much chromium were dissolved in a mixture of hydrochloric acid and bromine; to the neutralized solution 25 c.c. of a solution of ammonium oxalate, saturated at room temperature, were added and 100 c.c. of a similarly saturated solution of oxalic acid, all the liquid diluted with about 200 or 250 c.c. of water was electrolyzed. The results are given in

TABLE IV.

	Quantities taken for analyses.	Tension of the electrodes.	Density of Current per sq. centimeter.	Result.	Per ct.
1	Tin (Sn).....0.5518 gm. Cromium (Cr)..0.58 gm.	2.5 volts	1.2 amperes	0.5505 gm.	99.77
2	Tin (Sn).....0.5090 gm. Cromium (Cr)..0.5 gm.	4.0 "	5 "	0.5089 gm.	99.98
3	Tin (Sn).....0.5516 gm. Cromium (Cr)..0.53 gm.	3.9 "	5 "	0.5514 gm.	99.96

This table shows clearly a very perfect separation of tin and chromium by the method described, and the results obtained for tin are very satisfactory.

ELECTROLYTIC DETERMINATIONS.

The following is a resumé of the work which forms part of the "Contributions of the John Harrison Laboratory of Chemistry."

They treat of the electrolytic charge and of the electrolytic separation of metals, using a rotary anode. This anode, introduced by Exner, permits of very rapid work.

∴

J. R. Withrow has studied the electrolytic precipitation of gold from gold chloride, in the presence of potassium cyanide and sodium sulphide; he used Ingham's* apparatus, and the precautions laid down by Exner† were followed in the experiments with cyanide.

The first trials confirmed Exner's observations, showing, nevertheless, a smaller minimum of time than he indicated. The deposits, washed without interrupting the current, were of a beautiful yellow color, and formed very adherent microscopic needles.

The following table gives a series of trials undertaken with the object of ascertaining the minimum of time necessary for a total precipitation:‡

Nos.	Weight of gold present in gms.	K C N in gms.	Dilution in c.c.	Current in amperes.	Volts.	Time in minutes.	Weight of gold collected in gms.
1	0.2754	2.5	80	5	8.0 to 7.0	10	0.2746
2	0.2754	2.5	80	5		5	0.2706
3	0.2754	2.5	80	5	7.6 to 6.7	6	0.2720
4	0.2754	2.5	80	5	7.5 to 6.7	8	0.2754
5	0.2754	2.5	80	7	9.5 to 9.0	7	0.2748
6	0.2754	2.5	80	10	11.5 to 13.0	2	0.2667
11	0.2754	2.5	80	15		4	0.2750
12	0.2754	2.5	80	12	19.0 to 12.0	3	0.2621
13	0.2754	2.0	55	12-10	21.0 to 18.0	3	0.2742

This shows that eight minutes are sufficient with a current of 5 amperes, seven with one of 7 amperes, and four minutes with a current of 15 amperes.

A second series shows that with the same experimental conditions, it is not necessary to exceed 10 amperes, as a stronger current causes ebullition of the electrolyte.

Withrow has made, under the conditions he found most favorable, two series of experiments with solutions containing 0.25

*Journal of Amer. Chem Soc'y, XXVI, 1269.

†Journal of the Amer. Chem. Soc'y, XXVI, 1256.

‡Experiments 7 to 10 were excluded, as the author considered them inexact. Further, in experiment 11 he said he experimented with a current of 15 amperes, while the table only stated 10. I have re-stated this figure.

gram and 0.5 gram of gold; the latter are grouped in the following table:

Nos.	Weight of gold present in gms.	K C N in gms.	Dilution in c.c.	Current in amperes.	Volts.	Speed per minute.	Time in minutes.	Wt. of gold found in gms.
1	0.522	5	60	10	10.0 to 8.0	800	10	0.5216
2	0.522	5	60	10.0 to 10.2	10.0 to 7.3	800	12	0.5226
3	0.522	2.5	55	10.0 to 10.8	14.5 to 9.6	800	10	0.5222
4	0.522	2.5	55	10.0 to 10.3	14.0 to 9.4	810	12	0.5234
5	0.5465	3.5	60	10.0 to 10.5	8.3 to 7.0	790	12	0.5461
6	0.5465	5	60	10.0 to 10.2	9.3 to 8.3	790	1	0.1891
7	0.5465	5	60	10.5 to 10.5	8.3 to 7.0	800	3	0.4341
8	0.5465	5	60	10.0 to 10.3	9.6 to 7.1	825	5	0.5286
9	0.5465	5	60	10.0	8.6 to 6.7	780	7	0.5437
10	0.5465	5	60	10.3 to 10.0	8.3 to 6.3	790	11	0.5468
11	0.5465	5	60	10.0	7.8 to 6.8	790	12	0.5467

Experiments 1 and 2 show the precipitation is complete in from 10 to 12 minutes; 3 was made to show the effect of decreasing the quantity K C N; in this case it formed a deposit on the anode like yellow pollen, soluble in concentrated hydrochloric acid. Withrow obtained this deposit in his control experiments with a fixed anode when the precipitation lasted more than two hours.

Withrow obtained very good results by replacing potassium cyanide by sodium sulphide; but to work with this mixture it is necessary to put the sulphide first in the electrolytic cell and not to add the chloride until the anode is in motion. The results of experiments with a solution containing 0.25 grams of gold were within a trifle the same whether using cyanide or sulphide. In the latter case 0.5 gram of gold was deposited in twelve minutes.

Exner was the first to use the rotatory anode for the determination of tin. L. Witmer* used this method in the case where the electrolyte was ammonium sulphide. The ammonium sulphide was run from a burette into the electrolytic cell, then the salt of tin was introduced, and then sufficient water to make up a total volume of 100 c.c. was added. The anode was then put in motion and the current sent through the apparatus. The deposits of tin were washed with water, then alcohol and then ether. The following table gives the results obtained with stannic chloride; the added water was raised to boiling; the deposited tin, weighing 0.5 gram, was gray and crystalline; the anode revolved at a speed of

*Journal of the Amer. Soc'y, 1907, XXIX, 473.

350 to 400 revolutions per second. It was noticed that there was a very rapid precipitation of tin during the first ten minutes, then a sudden fall lasting during the deposition of the last traces of the metal:

Nos.	Quan. of sulphide in c.c.	Amp's.	Volts.	Time in minutes.	Tin collected in gms.
1	25	5	7.5	30	0.5069
2	25	5	8.0	30	0.5067
3	20	5	9.0	30	0.5070
4	20	5	9.0	20	0.5067
5	20	5	9.0	20	0.5064
6	20	5	9.0	20	0.5070
7	15	5	10.0	25	0.5067
8	20	5	9.0	1	0.0704

Nos.	Quan. of sulphide in c.c.	Amp's.	Volts.	Time in min's.	Tin collected in gms.
9	20	5	9	2	0.1279
10	20	5	9	3	0.1922
11	20	5	9	4	0.2475
12	20	5	9	5	0.2927
13	20	5	9	10	0.4796
14	20	5	9	15	0.7917
15	20	5	9	20	0.5070

When the weight of tin collected is one gram or over, the results are very high. This does not appear to be due to occluded water. Witmer has electrolyzed solutions of variable richness in tin and found that there was nothing occluded so long as the deposit did not exceed 0.8 gram, but above this weight the quantities of tin deposited were too high. He concluded that when using a rotating anode, and ammonium sulphide as the electrolyte, tin could be determined rapidly; that the deposit of tin was produced more rapidly by heating the electrolyte, but the presence of poly sulphides must be avoided, as they exercise a retarding influence.

Julia Langness* used a different anode from Exner, whose, as is known, was of a spiral form. The new anode consists of a platinum cap (or cover) seven centimeters in diameter and three centimeters deep, pierced with ten apertures each 1.8 c.m. long and 0.5 c.m. wide; the base is also pierced with a hole 1.3 c.m. in diameter; thus the free circulation of the liquid is assured. It should be equidistant from the walls of the cathode. The dilution should be weaker than with the spiral anode, for during the rotation of the anode, the liquid is forced into the space bounded by the cathode and the exterior wall of the anode. The volume of the electrolyte should not exceed 65 c.c. Julia Langness has studied the determination of different metals and has examined different electrolytic separations with the help of this anode.

In the case of copper the two anodes, spiral and cap, have been used in comparison with each other; among the numerous experiments that have been made we quote the following: 25 c.c. of cop-

*Journal of Amer. Chem Soc'y, XXIX, 459.

per sulphate, to which were added 1.2 grams ammonium nitrate and 25 c.c. of ammonia, were diluted to 125 c.c., raised to boiling and electrolyzed; with a spiral anode (current of 9 amperes under 8 volts) the precipitation was completed in fifteen minutes; with the new anode (current of 17 amperes under 6 volts) 0.4824 grams of copper were deposited in six minutes. The solution contained 0.4967 gram of copper.

Silver has given good results; silver was precipitated from a solution of nitrate and redissolved in potassium cyanide and two grams of cyanide were added in each case, the electrolyte was then diluted, raised nearly to boiling and electrolyzed. The following results were obtained with Exner's anode (shown in the first table) and with the new anode (second table):

Nos.	Volts.	Amp's.	Time in minutes.	Wt. of silver found in gms.	Nos.	Volts.	Amp's	Time in minutes.	Wt. of silver found in gms.
1	5	2.8	1	0.2046	5	5	2.8	5	0.5225
2	5	2.8	2	0.3391	6	5	2.8	7	0.5270
3	5	2.8	3	0.4858	7	5	2.8	10	0.5301
4	5	2.8	4	0.5043					

The precipitation was completed in ten minutes. Here are the results with the new anode, the differences of the current are largely due to the variation in the distance of the electrodes:

Nos.	Volts.	Amp's.	Time in minutes.	Wt. of silver found in gms.	Nos.	Volts.	Amp's.	Time in minutes.	Wt. of silver found in gms.
1	5	10	4	0.5304	4	5	9	2	0.5304
2	5	6	4	0.5306	5	5	9	1	0.5116
3	5	8	3	0.5306					

Some trials made with nickel showed that it was possible to precipitate 0.5 grams of metal from a solution containing ammonium sulphate in five minutes.

In the case of zinc, Julia Langness precipitated 0.25 gm. of metal in three minutes with a current of 13 amperes under 6 volts, the solution containing 4 grams of NaOH.

Platinum is deposited very well electrolytically, but it requires considerable time; this factor is considerably reduced by the new method, the metal is entirely precipitated from 25 c.c. of solution of potassium chloroplatinate with a current of 16 amperes under 10 volts.

But the best results are certainly obtained from palladium; the electrolyte was a solution of palladium ammonium chloride in

ammonia, 10 c.c. containing 0.268 gram of palladium. The following table gives a resumé of the experiments made, 20 c.c. of solution, to which 20 c.c. of boiling ammonia were added, and the whole then diluted to 60 c.c. with boiling water:

Nos.	Volts.	Amp's.	Time in minutes.	Wt. of palladium found in gms.	No.	Volts.	Amp's.	Time in minutes.	Wt. of palladium found in gms.
1	15	14	3	0.5358	3	17	11-20	1	0.4966
2	17	14-20	2	0.5357					

Rhodium deposits best from a solution of the double rhodium sodium chloride, $Na_2 Rh Cl_6$, to which a few drops of sulphuric acid are added. Julia Langness gives the figures grouped in this table:

Nos.	Volts.	Amp's.	Time in minutes.	Wt. of rhodium found in gms.	Nos.	Volts.	Amp's.	Time in minutes.	Wt. of rhodium found in gms.
1	7	8	15	0.0577	5	8	15	4	0.0573
2	7.5	8	10	0.0580	6	6.5	11	4	0.0563
3	8	9	10	0.0575	7	7	11	4	0.0567
4	8	9	7	0.0576					

The spiral anode was used in experiment 1. In the second part of the work Julia Langness studied the separation of different metals; 1st, gold from platinum and palladium; 2d, copper from platinum; 3d, silver from platinum, from copper, from nickel, from zinc, from a mixture of copper and platinum, and from copper in the alloy for coins.

Smith & MacCutcheon* have used the rotatory anode in a most interesting manner. It was found that in electrolyzing a solution of an alkaline chloride, as neutral as possible, with a rotatory silver anode and a mercury cathode, a colloidal solution of the hydroxide could be produced. If, for example, a solution of cerium chloride is placed in Hildebrand's apparatus, and is electrolyzed by a current of 0.8 to 0.02 amperes under 8 or 10 volts, a cerium amalgam is formed. This amalgam decomposes when all the chlorine has gone to the silver electrode, and the liquid in the interior compartment of the apparatus assumes a red color by transmitted light, it now contains a collodial compound of cerium. This compound gives the following re-actions:

With ammonia—red-brown precipitate.

With sodium chloride—red-brown precipitate.

*Journal of the Amer. Chem. Soc'y, 1907, XXIX, 1455.

With Potassium hydrate—after the addition of a dilute solution; the false solution assumes a pale brown tint, no precipitate; after treatment with permanganate and ammonia, a brown precipitate forms resembling cerium hydroxide.

Potassium chromate—red-brown precipitate.

Potassium iodide—red-brown precipitate.

Stannous chloride—red-brown precipitate.

Hydrogen peroxide—red-brown precipitate.

Hydrogen peroxide and ammonia—yellow precipitate, resembling hydrated cerium dioxide.

This red-brown precipitate which is formed when a salt is added to the mock solution is a mixture of oxides.

If the electrolysis is made with a rotary anode, no colloid is formed but a white precipitate of ferrous hydroxide appears. The colloid forms best with a difference of potential of 8 volts. With a smaller voltage (from 3 to 5 volts) nothing is produced; with a greater, there is a rapid precipitation.

False solutions of hydroxides can also be produced by the electrolysis of the chlorides of lanthanum, neodymium, prœseodymium and yttrium; also of ferric chloride.

The electrolysis of a solution of aluminum chloride gives, almost at once, a white, gelatinous precipitate; the filtrate is opalescent and remains so several weeks. Sodium chloride gives a precipitate soluble in sodium hydrate. Chromium chloride, using a current of 0.9 amperes under 5 volts, seems to form a colloid, sodium chloride precipitating chromium hydroxide.

These are the only chlorides with which Smith & MacCutcheon obtained good results. It appears that colloids can only be obtained from the sesqui-chlorides.

ABRASIVE GARNET PRODUCTION IN 1906.

The production of abrasive garnet in the United States in 1906 amounted to 4650 short tons, valued at $157,000. This falls short by 400 tons in quantity but exceeds by $8,905 in value the production in 1905, which was 5050 short tons, valued at $148,095. The average price per ton was $33.75, which is the highest since 1902, and a large increase over the average in 1905—$29.32. The production came chiefly from New York, a part coming from Pennsylvania.

No production of garnet was reported from North Carolina in 1905, but reports published in the mid-summer of 1907 indicate that the output for this year will be large, as the mine in Madison County is being operated with an estimated production of 125 tons of garnet a month. The product of this mine is used chiefly for abrasive purposes, though several very fine, clear gem stones are said to have been found .

Notes On Theory and Practice of Evaporation.

By Philip B. Sadtler, S.B.

THEORETICAL CONSIDERATIONS.

Heat Transmission.—Heat transmission is measured by four fundamental factors, namely, temperature, weight, space, and time. To be more specific, the common combination of units, in which we express heat transmission, is British Thermal Units, per square foot, per hour. Therefore, the coefficient of the heat transmission of a medium would be the figure which gives the number of British Thermal Units passing per hour from a warmer to a colder substance through one square foot of the medium for which we desire the coefficient.

It will readily be seen that the ability of the medium to transmit heat in a greater or less degree is governed by the following factors, namely, nature of the material, thickness of the medium, difference in temperature of the warmer and the colder substance, hence, we have

$$h = k \frac{t - t^1}{d} m.$$

When $h =$ heat transmitted, $m =$ time during which transmission takes place, $d =$ thickness of the transmitting medium, $t - t^1 =$ difference in temperature, and $k =$ constant dependent on the nature of the material.

From the above we see that,

$$k = \frac{d \times h}{(t - t^1) m}$$

whence we are able to determine constant k for any material by determining, d, h, $(t - t^1)$ and m for one square foot of heating surface. For practical purposes, where for a given material the limits of the factor d are quite narrow this is omitted and the constant becomes

$$k = \frac{h}{(t - t^1) m}$$

In the case of the transference of heat from one substance to another, for evaporative purposes, we have several possibilities:

that of heat passing *from* a liquid; *from* steam or *from* other gases; also heat passing *to* a body of liquid or *to* a film of liquid.

In evaporation work the case of heat passing from a liquid is not of very wide importance. Other things being equal k would be high in this case, but the difficulties involved in this method of heating necessarily outweigh those of steam heating. A high boiling liquid may be heated and made to pass through heating tubes, giving a high transference constant, but the velocity necessary for its passage through the tubes is great enough to make the idea unworthy of consideration.

In the case of saturated steam there is no necessity for an appreciable velocity directly in relation with the walls of the heating tubes. Unlike the case of direct heating, the effect is obtained by the latent heat of vaporization. Although the heat in large part is not due to difference in temperature between the steam and the liquid, being heated, there must be a quite appreciable difference in temperature to make effective use of the latent heat. The larger the difference in temperature the greater is the heat transmission of the metal walls.

As water dissolves air to a small extent the steam from the boiler always contains air in greater or less amount. This air tends to lessen the heat transmission so that it will be found in practice that better boiling takes place in the heating coil, where the velocity is considerable.

It can readily be seen, therefore, that the presence of *air in the heating steam is detrimental.* Just as air reduces the heat transmission so also does the water produced by condensation of the steam. The heat conductivity of water is far below that of a metal, so that a *steam coil containing a layer of water is not fully effective.*

The usual case of heating by other gases than steam is direct firing of boilers or evaporators, or the utilization of waste heat from furnaces, incinerators, etc. Here the transmission of heat is due to the difference in temperature and *the velocity of the gas.* It will readily be seen that if a body of cooled inert, non-condensable gas stays in contact with the wall of the heating surface the efficiency of the locality where that takes place is greatly reduced. On the other hand, in the case of steam the pressure back of the heating steam is cause for constant supply of the steam, which gives up its latent heat to the wall of the heating surface. A non-

condensable gas, to be equivalent in effect to a condensable gas, like steam, must be led against the heat transferring wall with considerable velocity to cause the rapid removal of cooled gas and prevent lodging of cooled gas in any small corners or devious places.

It is well recognized that the presence of moisture in non-condensable gases materially increases the heat conductivity. Waste gases from the combustion of very wet fuel or from the incineration of wet materials will contain very high percentages of steam and should not be overlooked as a good source of heat for evaporative purposes where their utilization is possible.

In such a case, however, we have usually a mixture of combustion gases and super-heated steam. The latter does not condense, but leaves the apparatus in a slightly cooled condition, because if the passage of the gas against the heating surface were regulated to cause a condensation of this super-heated steam, the velocity would be so low that the heat transmission would be too small for practical evaporative purposes. It is usually desirable, in using waste gases, for evaporation, to work between such limits as 650° and 375° or thereabouts.

Very little can be determined as to the theoretical side of the transmission of heat *to* different solutions and solids. In general it may be said that the completeness of the circulation of the liquid; the consequent rapidity of the disposal of the steam formed at the contact between the liquid and the heating surface; and the degree of mobility of the liquor are the chief factors for consideration here. More can be said later of interest and of value from a practical standpoint.

The heat transmission may be said to be greater when the liquid is in contact with the heating surface in as thin layers as possible. This is accomplished by allowing the liquor to spray or trickle over the heating surface or by bringing the liquor in contact with the surface in the form of a foam. When a film is in contact with the heating surface the evaporation may be said to be local, hence there is a local cooling tendency and consequent greater temperature difference between the liquor heated and the heating gas. This it will be seen will increase the heat transmission.

Single Vacuum and Multiple Effect Evaporators.—The purpose of the single vacuum evaporator is to accomplish a maximum amount of evaporation by taking advantage of the low boiling

point that is produced in liquids under a vacuum. If steam at five pounds pressure is introduced into the steam tubes of an evaporator in which the liquid is allowed to boil at atmospheric pressure the temperature difference between this steam and the boiling liquid (if the latter has the boiling point of water) is about 16°F. If, however, a vacuum of 25″ is maintained above the liquid to be evaporated the temperature difference is about 95°F., or some six times as great as in the above case. Thus for a given

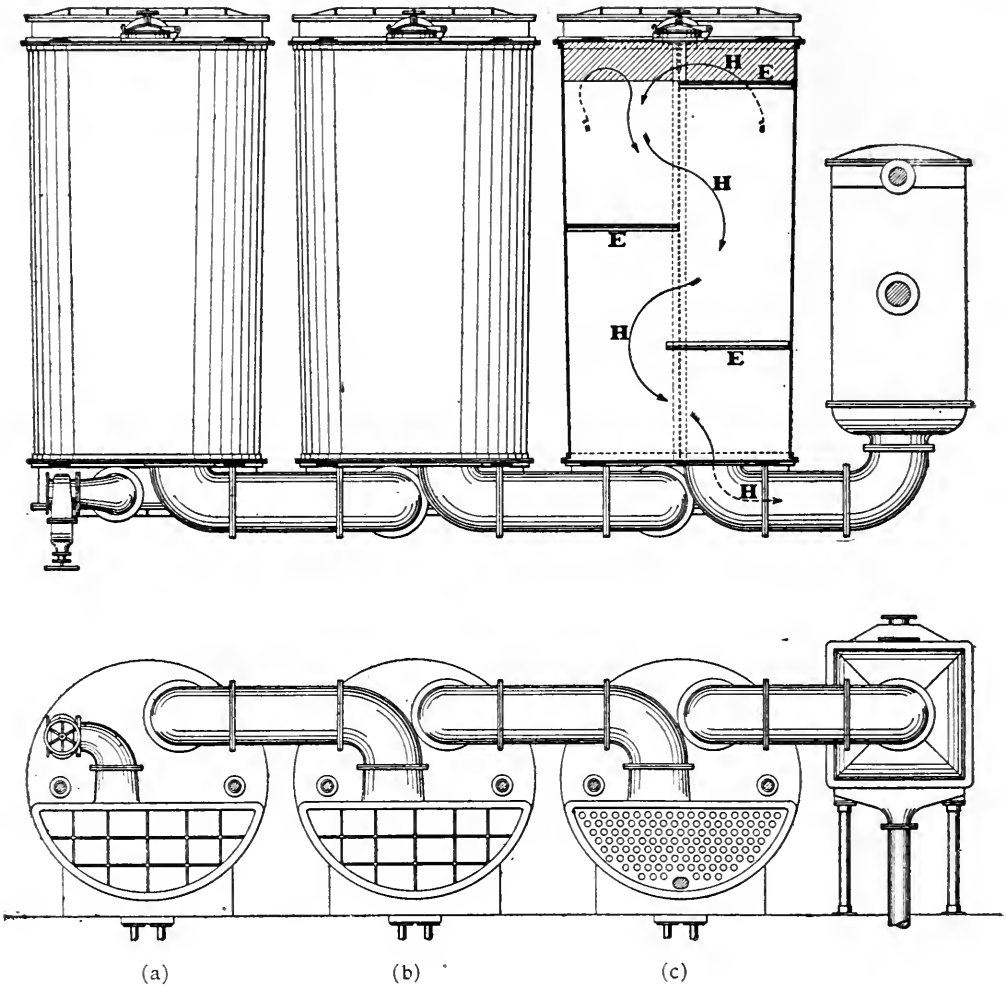


Fig. 1

vessel six times the evaporation can be accomplished in a given time, or for a given amount of evaporation the heating surface in the vessel may be one-sixth the size.

However, most liquids boil readily in an evaporator with smaller temperature differences than that just mentioned, namely 95°. So that the multiple effect system is used to a large extent for the

sake of economy. It is based on the utilization of the latent heat of the vapor arising from the evaporating liquor, to bring about further evaporation by heating the tubes of another evaporator. If the absolute pressure in each effect of the series is markedly lower than in the preceding effect, there is always obtained a temperature difference between the vapor of one effect and the liquid of the next.

For example, in the triple effect system shown in Fig. 1, let it be supposed that the steam enters the heating tubes in the bottom of the first effect (a) at atmospheric pressure, and that in the vapor spaces of the three effects have maintained in them vacua of 8, 16 and 24 inches. Then the temperatures are approximately: steam, 212°; vapor in (a), 195°F.; vapor in (b), 176°; vapor in

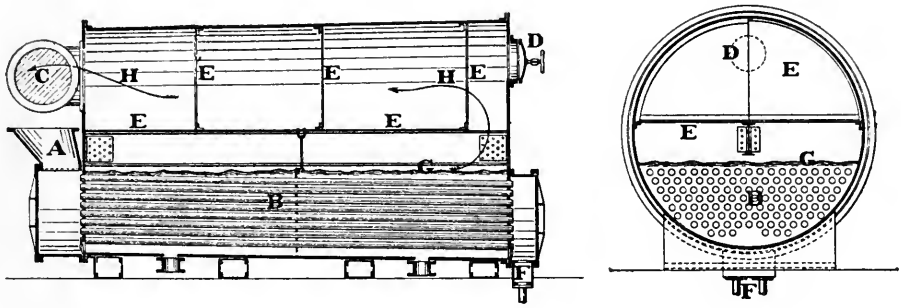


Fig. 2

(c), 140″. The average effect difference is about 24°F., which is quite sufficient for rapid boiling.

It is not difficult to see the economy in this system. The boiling of the liquid in all three effects is accomplished by the introduction of steam into the one. Theoretically there is accomplished an evaporation of three pounds of water per pound of steam entering the system. In actual fact due to radiation losses, etc., this figure is slightly under 3 pounds or above 2.7 pounds.

The amount of evaporation accomplished is due to, (1) the temperature and pressure of the entering steam; (2) the temperature and pressure of the steam produced in each separate vessel; (3) the extent to which the liquid is to be thickened by boiling and the nature of the liquid; (4) the height of the boiling layer of liquid in each vessel.

Fig. 2 gives an idea of the depth of the liquor in an evaporator for the best results. Evaporators having heating surface at the bottom of a very deep layer of liquor can not attain the greatest

efficiency. If the depth is considerable and if the liquid is of high gravity there is so great a hydrostatic pressure at the bottom of the liquid that its boiling point is thereby greatly raised. Unless the effect temperature difference is very great, the temperature at the bottom of the effect may be too high for the proper heat transmission. On the other hand, if the apparatus of the deep liquor layer is pushed to obtain the proper evaporation, the boiling point at the bottom is so great compared with the temperature in the vapor space that ebulition is violent and liquor is thereby lost.

For example, if we assume a case where the layer of the liquor is six feet deep and having a specific gravity of 1.4. Assume as in the above case that the vacuum is eight inches higher than in the preceding effect. It would be expected that the eight inches difference in vacuum would be equivalent to a temperature difference of 24°F. But we have a hydrostatic pressure of six feet of liquor at 1.4 specific gravity at the bottom of the effect. This, roughly speaking, is equivalent to eight inches of mercury. Thus the boiling temperature of the liquor at the bottom is the same as the temperature of the source of heat, hence there is no boiling in the bottom of the effect. This is an extreme case, but serves to show that deep layers tend toward inefficiency.

To be continued.

BUHRSTONES AND MILLSTONES.

The buhrstones and millstones produced in the United States in 1906 were valued at $48,590, an increase of $10,616 over the value of the output in 1905, though still below the records for 1901, 1902, and 1903, in each of which the value amounted to more than $50,000.

Though stone suitable for buhrstones and millstones is found in a number of States, only four—New York, Virginia, North Carolina, and Pennsylvania—reported production in 1906, the State values being as follows: New York, $28,848; Virginia, $15,611; North Carolina, $1,507; Pennsylvania, $2,624.

The value of the imports of these abrasives into the United States for each of the last three years has been approximately $32,000.

The production of abrasive materials in the United States in 1906 is the subject of a report by Douglas B. Sterrett, geologist, of the United States Geological Survey, published as an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," and now ready for distribution by the Survey.

The Relation of Magmatic Waters to Volcanic Action.

By Hiram W. Hixon.

The relation of magmatic waters to volcanic action, ore deposition, mountain folding and kindred phenomena has not been fully appreciated, and with few exceptions has not been recognized as of any importance. A glance at the table of analyses of eruptive rocks, taken from Kemp's Handbook of Rocks, will show the large amount of combined water which these rocks contain.

IGNEOUS ROCKS. THE GLASSES.	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	Loss. H_2O
1 Pumice, Cinder Cove, Cal.	79.49	11.6	0.33	0.49	1.64	0.09	1.52	4.04	0.68
2 Black Obsidian, Tewan Mounts	76.20	13.17	0.34	0.73	0.42	0.19	4.46	4.31	0.33
3 Red Obsidian, Yellowstone	75.52	14.11	1.74	0.08	0.78	0.1	3.63	3.92	0.39
4 Black Obsidian, Yellowstone	74.70	13.72	1.01	0.62	0.78	0.14	4.02	3.9	0.62
5 Obsidian, Mono Lake	74 05	13.85	Fr.	.....	0.90	0.07	4.31	4.6	2.20
6 Obsidian, Lipari Isl.	74.05	12.97	2.73	.....	0.12	0.28	5.11	3.88	0.22
7 Obsidian, Clear Lake, Cal.	74.01	12.95	.....	1.42	0.99	0.48	4.65	5.34	0.29
8 Perlite, Hungary	72.87	12.05	1.75	.....	1.30	1.1	Fr.	6.13	3.00
9 Pitchstone, Mussen	71.6	12.	1.0	.....	1.1	0.2	4.3	2.5	7.14
10 Pitchstone, Silver Cliff, Col.	71.56	13.10	0.66	0.28	0.74	0.14	4 06	3.77	5.52
11 Andesitic Perlite, Eureka, Nev.	65.13	15.73	2.24	1.86	3.62	1.42	3.96	2.93	2.43
12 Obsidian, Teneriff	60.5	19.1	4.2	0.3	0.6	0.2	3.5	10.6	.....
13 Hyalomelene, Germany	54.28	14.83	14.73	.....	7.02	3.65	1.27	4.22	.....
14 Pele's Hair, Hawaii	50.82	9.14	7.33	7.03	11.63	7.22	1.02	3.06	1.74
Rhyolites, Average 14									1.21
Trachytes, Average 6									1.38
Phonolites, Average 8									1.45
Granites, Average 12									0.6
Syenites, Average 7									1.2
Nipheline Syenites, Average 10									1.37
Basalts, Average 10									1.84
Diorites, Average 8									1 88

The combined water is shown as loss on ignition, and varies from 6/10 per cent. in granite to 7.4 per cent. in pitch-stone.

If we assume that the interior of the earth is made up of materials in the proportions found in these igneous rocks we are

forced to the conclusion that there is much more water in the interior magma than there is on the surface. None of the igneous or plutonic rocks shown in these tables contain less than 1/10 per cent. of combined water and even with this amount the water contents of the interior magma would be in excess of all the water in the oceans, lakes and rivers. Anyone who wishes to demonstrate the existence of water in fused lava has only to travel to the nearest active volcano and observe the expansion of steam and the formation of cavities in the molten mass. Not only is this possible, but if a piece of pitchstone or obsidian be placed in a forge and heated to a white heat, it will expand by the force of the contained water, and will be found to have passed into a kind of pumice. If the heating is stopped at the right time a core of unaltered pitchstone will be found, surrounded on all sides by a shell of expanded material. It is generally recognized that steam is the prime cause of volcanic action; the main point of difference of opinion has been the source from which the steam is derived.

Nearly all writers on this subject have held that the water was derived from the surface, either by being deeply buried in sedimentary rocks, or by passing through porous rocks against a pressure of steam, or by fracture of the ocean bottom.

Judd recognized the possibility that the water was a part of the original magma, and was given off on cooling in a manner similar to the discharge of oxygen by refined silver when cooling.

This statement is made in his work on Volcanoes, published in 1881, and is probably the earliest reference to the subject of magmatic waters.

The object of this paper is to elaborate the idea, and to show how it is possible that the water should have become a part of the interior magma; as well as its influence on all the geological and geographical structure of the earth.

It is necessary to go back to the beginning of things, in order to get a grasp on the conditions which made it possible. According to the Nebular Hypothesis, which is generally accepted as being the only satisfactory explanation of earth's genesis, the earth is an aggregation of matter from a nebula of matter in a dispersed form. According to our present knowledge expansion or dispersion causes lowering of temperature and aggregation or compression causes increase of temperature. Therefore, as the matter composing the earth gravitated towards a com-

mon center, the increase of temperature became sufficient to fuse and probably gasify or volatilize all of the matter of which it was composed. By the law of diffusion of mixed gases we find that they diffuse uniformly through the space occupied, without regard to the presence of other gases.

We also know that at high temperatures and under great pressure, gases are absorbed by solids and liquids, and that these are given off on cooling. Copper at high temperature in a converter contains several times its own volume of SO_2, and this is given off, when the charge is poured into moulds, and causes miniature volcanoes, ejecting copper in place of lava when a crust has formed over the surface. According to the law of uniform diffusion of mixed gases, whatever the mixture of gases which composed the earth in its earliest development, the mixture would be homogeneous until it began to cool. As cooling would begin at the surface the segregation of material would take place there according to the relative points of condensation. As nearly half of the matter composing the earth is oxygen, it would follow that there would always be a sufficient supply to combine with the small proportion of hydrogen present, and therefore we may assume that either in fact or in substance, water existed as a permanent gas above its critical temperature throughout the highly heated magma of the interior. As to the condition of this magma whether solid, liquid, or gaseous, we cannot claim to know much. This, however, we do know; it is highly heated, and according to our present knowledge of the increase of temperature with depth, we are justified in assuming that at a depth of 100 miles below the surface the temperature is as much as five thousand degrees centigrade, or nine thousand degrees fahrenheit.

This is about the critical temperature of all known substances, and as the critical temperature of a substance is defined as "the temperature at which it will remain a permanent gas, no matter what the pressure may be," we are justified in assuming that, regardless of the density due to pressure, all the magma at that depth is potentially, if not in fact, of a gaseous nature. It has been demonstrated that the viscosity of a gas increases with the pressure; and therefore, where pressures are measured in thousands of tons per square inch, it is possible for gases to acquire rigidity as great as solids, so long as the pressure is maintained.

Rigidity is a property of solids produced by cooling. Cooling causes reduction of the amplitude of vibrations of the molecules of matter with relation to each other. If a gas is subject to sufficient pressure to produce a greater density than if it were a solid, it is conceivable that it should acquire greater rigidity by the reduction of the amplitude of vibration of its molecules so long as the pressure is maintained. It is therefore possible that the interior magma may be gaseous and still have the required rigidity to resist tidal action. Assuming this condition of matter to exist in the interior, and at a depth of less than one hundred miles below the surface, it is possible to trace out some of the effects that would follow upon the loss of heat and the tendency of the water to travel toward the surface. First of all would be the formation of an atmosphere of incandescent steam and other gases, which would keep increasing in thickness and density as more and more of the magmatic water came to the surface. The substances which liquefied at the highest temperature would separate out at first as fine particles, much in the nature of fog or mist. This would go on accumulating until there had formed a sufficient quantity of the material to fall as rain, and be revolutionized by the ardent heat of the gaseous magma. Liquid areas of this molten material would form, supported by the gases of greater density, and constantly torn to tatters by eruptions of gases through them. In time a solid crust would begin to form over the liquid area, and this crust also would be torn and shattered by eruptions; until by accumulation of fragments it would cover the greater portion of the surface, the remainder being occupied by great boiling lava lakes, hundreds of miles in diameter. The craters of such volcanoes as then existed would dwarf all present craters. By continued escape of the magmatic steam the activity of these crater areas would be gradually decreased and the surface would be cooled until condensing water began the disintegration of the lavas and the formation of sedimentary rocks. By the process of eruption, disintegration and deposition, repeated throughout almost infinite time, we arrive at the present conditions. The question which interests us most is not how all this happened so many millions of years ago, but what bearing has it on the present? The most remarkable effect of the discharge of magmatic waters is volcanic action. The elevation of the zone of flowage due to rise of temperature is effected by heat

supplied from below by means of steam diffusing upward through the magma and accumulating below the zone of fracture.

Before proceeding further it is advisable to understand what we mean by steam at a temperature of 5,000 degrees centigrade and pressure of 45,400 atmospheres which corresponds to a depth of 100 miles. We know that one cubic inch of water will make a cubic foot of steam at atmospheric pressure and a temperature 100°C. Therefore $\frac{1}{1728}$ = density of water gas at one atmosphere $= \frac{6}{10000}$. We know that the density of a gas will vary directly as the pressure and inversely as the absolute temperature. Expressing this in symbols we have

$$D = \frac{6}{10000} \times \frac{45400}{1} \times \frac{373}{5273}$$

Therefore $D = 1.91$.

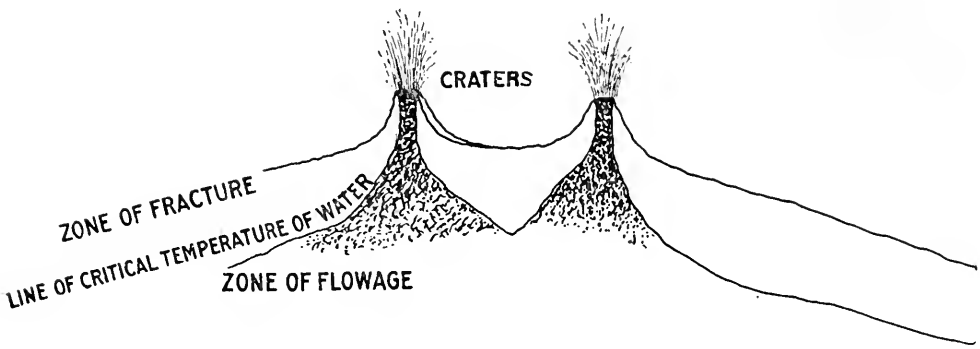
where D is the density we wish to determine P the pressure at 100 miles depth equal to 45,400 atmospheres. At absolute temperature which in this case is 5,000 C + 273. The 273 being added to the 5,000 C. to convert the absolute temperature.

This density is greater than water on the assumption that water above the critical temperature of 365 C. is a perfect gas and subject to the law which is assumed to apply beyond the limits of our present knowledge.

The steam is assumed to collect and pass upward toward the zone of fracture by diffusion through the zone of the flowage. Below the zone of flowage is the zone of potential gas in which all the materials are assumed as being equally diffused according to their relative abundance. The gases which condense to solids at high temperatures add to the thickness of the zone of flowage, the magmatic steam, hydrocarbons, SO_2, CO_2, HCl and other gases, diffuse toward the surface through the material with which they can no longer be associated because of its changed condition. The segregation of the materials of the central magma is caused by secular cooling and the different behavior of its constituent gases due to their varying critical temperatures. As the steam travels toward the surface it is subject to less pressure and it therefore expands until it finally condenses to water or is discharged as steam at atmospheric pressure. After the steam has collected sufficient heat and pressure to rupture the zone of frac-

ture, it penetrates along fault planes into rocks in which the temperature is below the critical temperature of water, and in which it ceases to act as a perfect gas and begins to condense to water, with the accompanying shock due to water hammer, and the opening and closing of the fault places.

These sudden collapses of steam, while elevating the zone of critical temperature, produce the earthquakes which immediately precede an eruption and announce the approaching danger. The final outburst is frequently preceded by a large discharge of mud



MAGMA ABOVE CRITICAL TEMPERATURE OF ALL SUBSTANCES POTENTIALLY GASEOUS, CONTAINING WATER GAS

Ideal section of volcanoes actuated by magmatic steam, showing intersecting zones in which steam collects beneath each crater, illustrating how they act independently of each other. The steam supplying the heat necessary for fusion of the lava which may come from any horizon.

and water, after which the steam flows up from below so rapidly as to elevate the temperature of the crater to the fusing point of the rocks along its path. Then begins the discharge of pumice and dust followed by scoria and other lavas more or less dense, and containing less water as the density increases. The first discharge of dust may be simply pulverized rock, or it may be a lava containing so much water as to be atomized by the explosion or expansion of the steam it contains.

As it appears probable that under proper conditions, water and rock are miscible in all proportions, we may expect to find lavas containing so much water that they are atomized by its expansion.

When the accumulated steam has escaped, the lava in the crater flows back into the depths and solidifies, effectively plugging it up until after a long or short period enough steam has collected to

cause another eruption. This blowing out of the lava by the expansion of the magmatic steam is similar in action to the uncorking of a bottle of champagne or mineral water, which, if not properly done, will result in the gases discharging the contents of the bottle before the operator is prepared for it.

In places where the magma, supersaturated with steam, has been carried into fault planes, it becomes dikes, which later may be exposed by erosion or which may accumulate below an elastic rock, such as shale, as lacoliths.

At a depth of seven miles below the surface the temperature is probably about 365°C., which is the critical temperature of water. The density of steam would be 1.1 at this temperature and pressure, according to the law above mentioned. As the zone of flowage and high temperature is much higher under a volcano than under other parts of the crust, it follows that the steam above the critical temperature comes nearer to the surface before condensing. Under the reduced pressure it would expand and be less dense. At a depth of two and a-half miles the pressure would be about 1000 atmospheres if the rock density averaged 3. Under this pressure, and at the critical temperature, the density of steam would be .37. Sudden condensation would, therefore, be accompanied by a reduction of volume, and a sharp shock. At the depth of seven miles, where the density is 1.1, condensation would not take place, because of the higher temperature; and no shock would be possible because there could be no sudden reduction of volume. This explains why the water hammer earthquakes which immediately precede a volcanic explosion, come from shallow depths, as compared to the other type of quakes, caused by faulting, which goes clear through the zone of fracture and may extend to depths of many miles.

The point of relationship between them is that they are both caused by the escape of magmatic waters. In the latter case the fault is due to contraction of the inner magma which supports the crust. This causes the crust to crush and settle by its own weight.

The contraction of the magma is due to loss of heat and steam which escapes towards the surface; and, therefore, this loss of magmatic waters is one cause of earthquakes of both types, as well as one cause of faulting and folding. Faulting and folding, by this theory, are effects, and not necessarily causes. A photo-

graph of the moon will show that the surface is covered with craters on a gigantic scale, much the same as we would imagine to have been on the earth had they not been destroyed by the disintegrating action of water. The diameter of some of these lunar craters is estimated to be as much as eighty miles and the depth thousands of feet. If the discharge of magmatic water is to be accepted as the cause of terrestrial volcanism, what about the moon, where no water exists on the surface? If water existed on the moon, in the course of the long lunar day, when the sun shines on one side for fourteen of our days, water would be boiled, while during the night the degree of frost would expand the ice to such an extent that the disintegrating effect of even a small amount of water would be multiplied many times what it is on the earth.

It would be like having fourteen days of the equator followed by two weeks of the North pole. On the earth we have winter once a year, while on the moon it occurs each month of our time. The water on the hot side would be vaporized and condensed on the cold side, so that if water existed on the moon there would be a constant cloud forming at the line of illumination, and this would be visible even to the naked eye. That no such thing occurs is proof positive that the moon is without an atmosphere of any kind. What has become of it? There have been several suggestions offered to account for the lack of an atmosphere on our satellite, among which are that it has been absorbed by the moon itself, or that a comet came along and stole it away. The real solution of the problem is probably that the kinetic energy of gases is greater than the gravity of the moon can overcome. As fast as gas of any kind was discharged from the craters, it expanded into space, and was eventually taken away from the moon by the greater gravity of the earth. The earth, therefore, has robbed the moon of its atmosprere and hydrosphere and the moon has never felt the effect of disintegration and sedimentation as the earth has. The mass of the moon being only one-eighty-first part of that of the earth, and its force of gravity at the surface only one-sixth, we can understand how the stronger attraction, coupled with the tendency of gases to expand into space, would result in the atmosphere of the moon being picked up, molecule by molecule, and added to that of the earth.

What bearing this theory has on the cause of volcanism on

the earth may now be shown. The presence of past volcanic activity on the moon is unmistakable, and the cause (water) is absent, having been added to the earth as rapidly as liberated. Therefore there was never an opportunity for surface waters to get into the interior of the moon, and to cause the volcanic action which evidently occurred there. But the evidence in the shape of enormous craters are there; and the conclusion is that the magma having parted with its steam, volcanic action ceased. We may, therefore, feel sure that when the earth loses all its magmatic water, volcanic action will cease, no matter how much water may be on the surface.

Of the many other ways in which magmatic waters are producing results which are not generally recognized as caused by them a few may be mentioned.

The water on the surface is being constantly added to by the discharge of steam from volcanoes, water from hot springs, geysers, etc. The ocean areas are therefore being added to unless by the process of folding the depth is increased.

The waters discharged by hot springs and geysers can be proven to be of magmatic origin in several ways.

They contain a certain amount of heat. If we calculate the amount of hot rock required to supply that heat we will find the volume of rock to be so large that the water could not come into such contact with it as would extract the heat. For example, a calculation of this character was made on the water discharged by the geysers and hot springs in Yellowstone Park. And while no claim for great accuracy can be made it was found that it would require the heat from one hundred and forty cubic miles of lava, cooled through fifteen hundred degrees of heat, to furnish the heat in the water discharged in one hundred thousand years.

The discharged waters are known to contain hydrochloric acid and carbonic acid and other ingredients characteristic of volcanic emanation.

Hot springs are distributed along fault planes in the same manner as volcanoes, and while some of the water may be of surface origin, the greater portion is magmatic water. In nearly all cases hot spring water contains so much silica and lime in solution that the deposition of these along the path of ascent completely isolates the spring from surface waters, finally fills the channel

and chokes the spring to death or causes a new one. The water laden with these soluble salts penetrates the rocks in all directions, before reaching the surface and by depositing the minerals from solution acts as a cementing agent on all porous rocks, and isolates its channel as effectively as a casing excludes surface water from an oil well.

The last step in the process of isolation is to build up a cone of geyserite or travestine at the surface.

The minerals in solution may change at different levels, as the waters pass through rocks of different degrees of solubility. Thus, for example, waters that rise through eruptive rocks may discharge through limestone at the surface; and drop their silica and iron in favor of lime while passing through the lime. This is probably true of Mammoth Hotsprings in Yellowstone Park.

The deposition of ores from magmatic waters is a subject that is deserving of more attention than has been given to it, but there are hopeful signs for the future. Surface waters laden with air as an oxidizing agent can alter a sulphide ore body, or deposit such beds of iron as are plainly of sedimentary origin; but they cannot deposit unaltered sulphides. The waters which deposited ores came from depths that surface waters never reach.

The ascension of hot solutions, along lines of least resistance, is the only theory by which rich shoots can be sufficiently accounted for in vein filling.

Dolitimization of limestone, in the vicinity of ore deposits (such as are in southwest Missouri, and at Aspen, Colorado), is another effect of magmatic waters containing sulphate of magnesia in solution. The cementation of sandstone, converting it into a flinty quartzite, is another and more frequent effect. In fact, the influence of magmatic waters is to be found distributed throughout the lithosphere, the hydrosphere and the atmosphere.

It is one of the greatest forces acting upon the earth, and has been given little recognition for the great work accomplished. Mountain folding is a characteristic example. It has been admitted by eminent physicists, who have examined the subject, that it is impossible to account for the contraction necessary to mountain folding by simple secular cooling. If, however, we assume that the greater portion of the water now in the oceans was at one time a part of the central magma, the difficulty disappears. We have also considerable evidence from the analysis of volcanic

rocks that there is still more water combined with the central magma than exists on the surface. From this we may infer that there will be a further reduction of the earth's diameter followed by more earthquakes and mountain folding and kindred phenomena. Besides Prof. Judd, whom I have quoted, Chamberlin, Hill and others have referred to magmatic waters in connection with volcanic action, but have not followed the subject farther than to show the presence of steam as being a feature of the explosion.

Osmond Fisher's Physics of the Earth's Crust, 1889, contains much of the matter in this theory but different in detail. Fisher assumes convection currents in a fluid substratum, for which the above theory substitutes diffusion of the steam and occluded gases through the zone of flowage.

GEOLOGY AND WATER RESOURCES OF THE ATLANTIC COASTAL PLAIN.

Important Cöoperative work Between the State and National Surveys.

A geologic study of the Atlantic Coastal Plain of the United States is being carried on by the United States Geological Survey in cöoperation with the official surveys of the various States concerned. Although the need for such work was long recognized, plans for its inauguration were not perfected until about a year ago, when, in response to an invitation sent out by the Director of the National Survey, the State Geologists from the various States came to Washington and met in conference those members of the Federal organization most deeply interested in the proposed investigation. At this meeting, which was held December 31, 1906, it was decided that the cöoperative Survey of the geology of the coastal plain States should be made, with especial reference to the underground water resources of the region.

In accordance with the views expressed at the conference a Supervising Board was formed, with Professor William Bullock Clark, of Johns Hopkins University, as chairman, the other members being the State Geologists of the cöoperating States and, from the National Survey, the chiefs of the geologic and water resources branches, the Chief Paleontologist, and the geologist selected to supervise the investigation.

The State Geologist of each State has general supervision of the work in his State, while the Chief Geologist, Chief Hydrographer and Chief Paleontologist of the Federal Survey act in their respective official capacities. Mr. T. Wayland Vaughan, the geologist selected to supervise the investigation, has charge of the cöordination of the work between the different States represented and of the geologic correlations.

As a result of many conferences it has been decided to issue for each State cöoperating a report in accordance with the following outline:

1. Topographic description, which will include an account of the surface relief and drainage features.

2. Stratigraphy, including brief descriptions of the various geolgic formations, from the oldest to the most recent, the thickness of the formations, the physical and chemical characters of the rocks composing them, and the geologic structure. This part of the report will also include lists of the fossils that have an important bearing on the determination of geologic horizons.

3. Hydrography, including an account of the stratigraphic distribution of the underground waters—that is, of the geological formations in which the waters occur—a discussion of the amount of supply, qualities, and uses of the waters, and a detailed description of their geographic distribution.

4. Cartography. Each report will include a topographic map of the Coastal Plain region of the State on the scale of 1:500,000 to 1:1,000,000 (that is, approximately, 1 inch = 8 miles or 1 inch = 16 miles), the elevations to be shown by contour lines representing intervals of 50 feet. This map will be used as the base for (1) the areal geological map, which will show the geologic formations by colors and patterns; (2) a hydrographic map which will show the surface outcrop of each water-bearing bed, and, by contour lines of equal elevation, the position of its upper surface with relation to sea level; (3) a hydrographic map showing the water resources for each locality, classified according to source; the important physical and chemical properties of the waters, and the arrangements for distributing the waters for domestic and industrial purposes, i. e., wells reservoirs, etc.

On the plan outlined, the reports can be published either by the State Survey or by the National Survey as may be desired.

The following States are cöoperating in the work:

New Jersey, Prof. H. B. Kümmel, State Geologist.

Maryland, Prof. W. B. Clark, State Geologist.

Virginia, through Prof. W. B. Clark, who is directing a study of the Coastal Plain of that State.

North Carolina, Dr. Joseph Hyde Pratt, State Geologist.

South Carolina, Mr. Earle Sloan, State Geologist.

Georgia, Prof. W. S. Yeates, State Geologist.

Florida, Prof. E. H. Sellards, State Geologist.

Alabama, Prof. Eugene A. Smith, State Geologist.

Mississippi, Prof. A. F. Crider, State Geologist.

Preliminary arrangements have been made for reports on the States from New Jersey to Mississippi, inclusive, and work has been done during the last year in all except Mississippi. Lack of available funds has prevented the execution of all the work as first planned. It is hoped that the studies can be extended so as to include the whole Coastal Plain area of the United States—that is, to extend from Cape Cod southward through the Atlantic States, westward through the Gulf States to the Rio Grande, and northward along the Mississippi to southern Illinois. Should this plan be carried out it will yield a cöordinated history of the physiography, stratigraphic geology, and water resources of this extensive and important area.

Accounts of the work done in accordance with this plan will appear from time to time.

Mining and Metallurgical Section.

(Stated meeting, held Thursday, March 19, 1908.)

Notes On Copper Mining in the American Colonies.*

By Edgar T. Wherry.

The possibility of the occurrence of mineral wealth in the New World naturally attracted the attention of the colonists from the very earliest times. Aside from the fool's gold, which in those days entrapped the unwary, as it does even now, the iron ore with which the country abounded was the first object of mining operations. The beginnings of the iron industry have been well told by many writers, but the search for copper, which also commenced in the early days, has received little consideration. The following data, obtained in the course of a study of the copper deposits of Pennsylvania, seem, therefore, worthy of publication.†

The colony of New Amsterdam was started by the Dutch in 1624, but only fragmentary records of events were preserved at first. From the selections of these copied in Brodhead's History of New York, and Hazard's Annals of Pennsylvania, it appears that the earliest mention of copper occurs in 1659, in the following words:

"We lately saw a small piece of mineral, said to have been brought from New Netherland, which was such good and pure copper, that we deemed it worth inquiring of one Kloes de Rutyer about it * * * . He asserted that there was a copper mine at Meenesink and that between the Manhattans and South River was discovered a mountain of crystal."

In Hazard's Register of Pennsylvania, Volume I, page 439, is

*Part I of paper on Triassic Copper Mines in Southeastern Pennsylvania, as presented at the meeting.

†I am greatly indebted to Mr. George W. Geist for calling my attention to several of the publications herein referred to, and embrace this opportunity to express my thanks for his valuable assistance.

an article headed, "Meenesink, Mine Holes, &c.," in which Samuel Preston describes a surveying trip to Northeastern Pennsylvania, taken in 1787, with the express purpose of "learning more particulars respecting the Mine Road to Esopus," and the Meenesink settlement which had been observed by Nicholas Scull and John Lukens on a visit to the region in 1730.

"At Paaquarry Flat, on the Delaware, above the Blue Mountains," he found a settlement, "the inhabitants being all Hollanders," and one of them, Nicholas Depuis, gave him the following account of the mining operations:

"That in some former age there came a company of miners from Holland; supposed from the great labor that had been expended in making that road about 100 miles long that they were very rich or great people; in working the two mines, one on the Delaware where the mountain nearly approaches the Lower Point of Paaquarry Flat, the other at the north foot of the same mountain, near half way between Delaware and Esopus; that he ever understood that abundance of ore had been hauled on that road, but never could learn whether it was lead or silver."

Preston further learned from New York surveyors whom he met that the Mine Holes and Mine Road were recognized by them as "a work transacted while the State of New York belonged to the government of Holland; and must have begun many years before the English occupation, in 1664."

The Meenesink or Paaquarry Flat locality is situated on the Delaware River, nine miles northeast of the Water Gap. The quartzite of the Kittatinny Mountain carries here considerable amounts of copper and silver, which are being exploited, though with little success, at the present day; and below the recent workings the old tunnels driven by the Dutch are still to be seen.

The "north foot of the same mountain" evidently refers to Ellenville, New York, where copper, lead and zinc were actively mined fifty years ago. Here, also, openings of considerable antiquity are known to exist, and, although usually attributed to the Indians, were probably the work of the Dutch, as above described. In fact, since this is the nearer to the Hudson River, the principal path of traffic in those days, it is very likely that it was the first to be discovered. The "mountain of crystal" noted by De Ruyter was no doubt one of the veins of crystallized quartz, so common in the Kittatinny Ridge.

A somewhat similar problem is presented by the Solebury copper mine on Bowman's Hill, two miles south of New Hope, Bucks County, Pennsylvania. From Battle's History of Bucks County the following description is taken:

"The main shaft, running northwest from the entrance, is four feet wide by seven feet high; sixty feet from the entrance it crosses a chamber about fifteen feet in diameter, seven in height, with a stone pillar near the center. The drift extends twelve feet eastward from the chamber. To the right of the latter is the main shaft to the surface, six feet in diameter and about thirty in height, which descends through the chamber to a depth of twenty-two feet; and at the bottom a second drift is encountered extending northward fifteen feet. A tradition concerning the existence of the mine has always been current in the neighborhood. * * It was discovered and explored by John T. Neely in 1854.

"The land was originally seated by William Coleman, sold to a company, by them to Robert Thompson in 1753, reserving the right to dig for copper, lead, or iron ore. * * * There is no evidence that they or any subsequent purchasers made the original excavations. Indian tradition asserts most clearly, however, that 'white men' worked the mine. Who they were, whence they came, and what disposition was made of the minerals they extracted are among the secrets of history."

Now it is true that no mention of this mine is made in the records of New Netherland. But it seems quite reasonable to suppose that the Dutch, guided, of course, by the Indians, traveled sixty miles down the river from Meenesink to seek for ore here also.

That copper mining engaged the attention of the settlers in New England at an early date is generally recognized. Thus in the Records of Massachusetts for October, 1651, we find the following note:

"Upon the request of our present Governor, John Endecott, Esquire, this Court doth graunt him three hundred acors of woodland, tendinge to the furtherance of a copper worke he intends to set up in a place called Blind Hole neere to a farm formerly graunted him, the said land not being formerly graunted, provided he set up his said works within seven years."

It appears, however, that the said works were not set up, for no later mention of this locality can be found.

A more successful enterprise was that near Simsbury, in Connecticut. The deposit was discovered about 1705, and operations were begun in 1709 by the first mining company chartered in America. The results were at first somewhat disappointing, for in 1718 the Records of the Colony say:

"* * * The copper mines within this colony, by the orderly and effectual management of them may in time to come be of great use and advantage * * * although at the present time they be of small advantage to anybody, and a fruitless expense of money to the proprietors * * * ."

The later history of the mine,—the coining of the Granby coppers from the metal obtained, and its use as a prison during the war,—is so well described in the various stories of the colony that no further account need here be introduced.

Although the Solebury mine can claim precedence in Pennsylvania, as far as actual date is concerned, the first mines opened by the English (and German) colonists were destined to become of far greater importance. The deposits must have been discovered almost immediately after the first settlement, for William Penn, in writing to Lord Keeper North and other friends in England, in 1683, mentions the existence of "mineral of copper and iron in divers places."

As to the year in which mining was begun local historians are not entirely agreed, and although it is often given as 1720, there are some suggestions of activity at an earlier date. In 1703, the deputies of Penn had granted to Nathaniel Puckle a tract of "four hundred and fifty acres of land fronting on the present northeast line of Limerick, * * * in the southwestern portion of the present Township of Frederick," described as rough and unimproved;* and it seems not improbable that some work was carried on at that time, although it is not until 1722 that we find Roger Edmunds, son-in-law of Puckle, organizing a company to operate the copper mines. This company was unsuccessful, and the next year they were sold out by the sheriff to Andrew Hamilton, Esquire, of Philadelphia. He in turn formed an association among his friends, under the title of the Perkiomen Mining Company, but no extensive development of the property was undertaken until about 1740.

---

*Bean's History of Montgomery County, p. 843.

Christopher Geist, a German mining engineer, was then brought over to carry on the work, and drove a tunnel westward from the Perkiomen Creek to a distance of over 2000 feet; it there connected with three shafts and with a drainage tunnel opening on Mine Run, which is still accessible and can be followed in for some distance. Sufficient ore was obtained and sent to England to justify its inclusion among the principal exports of the Province of Pennsylvania by Sir Charles Whitworth,* but about 1770 the mine was closed, the property sold and the locality forgotten. Scull's map of Pennsylvania of 1759 shows two mines in this region, the one just described and a "Caledonia mine," about two miles to the northwest, of the history of which nothing is known.

It is, however, not only in the Records of the Province of Pennsylvania that information concerning these early mines is to be found. A German journal, the Breslau Kunst und Natur Geschichten (Supplement III, page 46) published about 1720, contains an interesting, though rather rambling and indefinite account of them. In this, particular reference is made to a copper deposit discovered in 1717 on a tract of land called New Hanover, by John Henry Sprogel, the ore from which had been assayed by Herr Marggraff, of Berlin, and found to contain, in four ounces, one ounce of metallic copper and four grains of gold, which the writer, "a learned physician of Frankfurt-on-the-Oder," wisely considers "so strong that it would be safe to neglect the copper and count upon the gold." Sprogel's property is at present the Brendlinger farm, about three miles east of Boyertown; several openings are still visible there, but whether they were made by Sprogel, by Geist, or by later workers is unknown.

The account also states that other mines had been opened about the same time (1717), evidently referring to the Perkiomen mine, above described, and perhaps to the Gap mine, in Lancaster County, which, according to another authority, dates from 1718.† And finally, it mentions the finding of copper "by a moor" on the Schuyler farm, in "West Jersey, ten miles from New Yorck," in 1714. The Schuyler mine therefore antedates these various Pennsylvania mines, with the possible exception of the Perkio-

*An account of the trade of Great Britain, London, 1776.

†Doble, C. Annual Report of the Secretary of Internal Affairs of Pennsylvania, 1875.

men; but nothing can be added to the excellent account of it which recently appeared in these pages.*

As a summary of this paper the following table is introduced, including all of the copper mines believed to have been opened in the American Colonies before 1725, with the approximate dates when operations were begun. But as the incompleteness of the records renders the exact order uncertain, the list must in no way be regarded as final:

Ellenville	New York,	before 1650.
Meenesink,	New Jersey,	before 1650.
Solebury,	Pennsylvania,	before 1650.
Simsbury,	Connecticut,	1709.
Schuyler,	New Jersey,	1715.
Perkiomen,	Pennsylvania,	1717.
Brendlinger,	Pennsylvania,	1717.
Gap,	Pennsylvania,	1718.

PRODUCTION OF CORUNDUM AND EMERY IN 1906.

Corundum and its modification, emery, furnish the best natural abrasive known, except diamond, the use of which is limited by its high price, and the purer forms of corundum make an abrasive material which is probably the equal of any of the artificial abrasives. The abrasive quality of emery is determined by the quantity of the iron ore (magnetite or hematite) mechanically mixed with the corundum, being better as the percentage of iron is smaller. The production of these minerals in the United States is limited by the scarcity of the supply and by competition with Canadian corundum, Asia Minor emery, and artificial abrasives.

Corundum has been mined in the United States for abrasive purposes in North Carolina, Georgia, and Montana, but with the exception of a small quantity from Kansas, the whole production in 1906 came from Massachusetts and New York. The output for 1906 amounted to 1160 short tons, valued at $44,310, as against 2126 short tons, valued at $61,464, in 1905.

The demand for corundum and emery and other abrasives, natural and artificial, is reported by Douglas B. Sterrett, geologist, United States Geological Survey, in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is now ready for distribution by the Survey.

---

*Granberry, J. H. The Schuyler Mine. Journal Franklin Institute, 164, 1907, 13-28, 217-223.

Section of Photography and Microscopy.

(Stated meeting held Thursday, March 12, 1908.)

Brief Notes On the Early History of Photography in Philadelphia.

By Alfred Rigling, Librarian of the Institute.

In the autumn of 1839, accounts began to appear in the newspapers and magazines of the United States of the achievements of Louis Jacques Mandé Daguerre, in the field of photography.

One of the earliest notices of the advance in this art was communicated to the editor of the United States Gazette, by Alexander Dallas Bache, and reprinted in the *Journal* of the Franklin Institute for September, 1839. This was followed in the October number by a brief note extracted from the Mechanics' Magazine, London, and in November there appeared a translation, by Prof. John F. Frazer, of the original article of Daguerre.

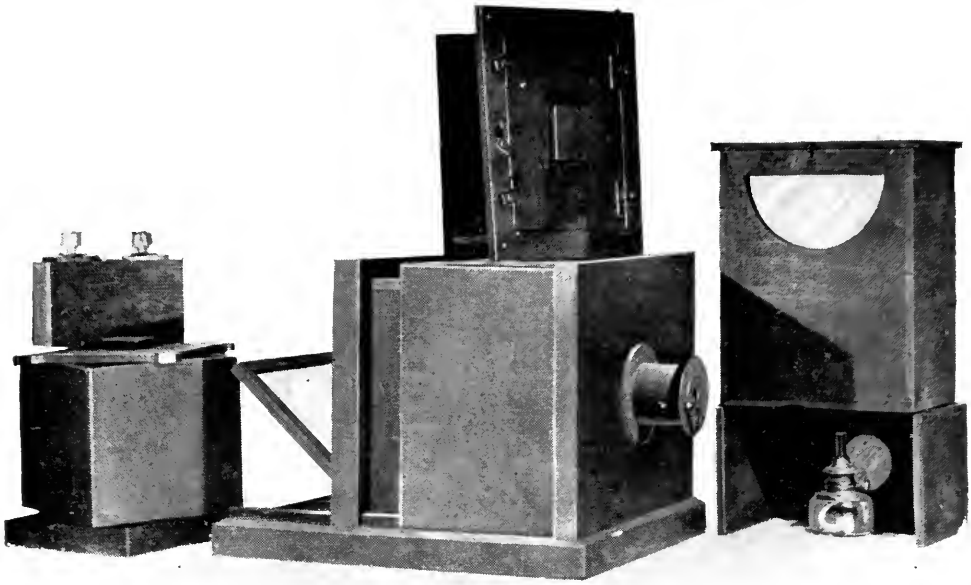
This contained a very full description of the process with illustrations of the apparatus necessary to carry out the various stages of the operation.

Soon after news reached Philadelphia of the latest developments in the art of picture-taking Joaquim Bishop, a chemical instrument maker, then living at 213 Cherry Street, and assistant to Dr. Robert Hare, Professor of Chemistry at the University of Pennsylvania, constructed three cameras after the description of Daguerre. One of these came into the possession of Dr. Paul Beck Goddard, an associate of Dr. Hare at the University, another was turned over to Justus Saxton, a mechanic connected with the United States Mint, and the third became the property of Robert Cornelius, a sheet metal worker, who was in business at 176 Chestnut Street.

Dr. Goddard soon discovered the use of bromine as an accelerator, thereby reducing the time of exposure and making portraiture possible commercially.

To Robert Cornelius belongs the credit for having brought to perfection the making and polishing of silvered copper plates upon which the photographs were taken.

As is always the case with new discoveries, so there were in Philadelphia in those days, the scoffers, and among them was a physician living near Twelfth and Arch Streets, who laughed at the idea of copying objects with the aid of sunlight. He soon had excellent reasons for changing his mind, and at the time of his



Sensitizing outfit Camera and plate holder Developing box

Dauguerreotype camera and accessories made by Joaquim Bishop, 1839.
Presented to the Franklin Institute by Dr. Paul J. Sartain.

death, in 1854, he was one of the ablest writers on the subject of photography in the United States.

Dr. Goddard lived on Ninth Street below Market, and one of his first pictures was a view, from the window of his home, of the University buildings on the opposite side of the street—the site of the present post office.

Justus Saxton also began taking pictures, and among his earliest attempts were views of the old Arsenal and the High School.

The first portrait was made in 1839, by Prof. Walter R. Johnson, a scientist of much note, who is best known for his elaborate report on American Coals, made to the Navy Department and published in 1844.

Dr. John E. Parker, a dentist, living at 411 Mulberry Street (now Eleventh and Arch Streets), surpassed all others as a photographer of out-door views, street scenes and buildings; he also did much toward perfecting the photographic apparatus of those days.

The tradition is that Dr. Goddard communicated to Robert Cornelius his experiences with bromine, and its effects upon the time of exposure, and that the latter gave up his metal business and established the first photographic studio, at Eighth Street and Lodge Alley, near Chestnut Street; the first professional picture being that of John McAllister, the optician.

It has not been possible to find any record in the Philadelphia directories of the Cornelius daguerreotype studio, and it is therefore not likely that he was in business for any great length of time.

It is stated that he was succeeded by W. & F. Langenheim. These gentlemen opened a studio at 26 and 27 Exchange Street, during the year 1842, or early in 1843, and became the leading photographers in Philadelphia, and also attained an international reputation.

A philosophical instrument maker, A. Mason, by name, produced an excellent copy of an engraving by the light of a small gas burner. This, it is said, was the first picture ever taken by artificial light.

Mason also succeeded in making daguerreotypes on steel.

Dr. Goddard's medical practice and his duties at the University prevented him from continuing his experiments with the daguerreotype, and he sold his camera and accessories to Mr. John Sartain. Later they came into the possession of the late Mr. Samuel Sartain, for many years treasurer of the Institute.

Through the kindness of Dr. Paul J. Sartain, this apparatus has recently been deposited in the Institute and forms an interesting addition to the collection of historic models.

It consists of a sensitizing box, a camera and a developing box.

Briefly described the process is as follows:

After the silvered copper plates have been thoroughly cleaned with nitric acid, they are ready for the sensitizing box. Here they are exposed to the vapor of iodine, and when uniformly coated they are placed in the camera.

This piece of apparatus resembles the modern studio camera in

a slight degree. It has no bellows; the rear portion of the box fits snugly into the front portion and slides freely back and forth. The inside of the rear portion is lined with black velvet and the front portion is painted black.

An achromatic single lens, brass mounted, with fixed diaphragm and metal cover is fitted into the front of the box.

Behind the ground glass is a mirror, hinged at the bottom, which drops outward and may be fastened at an angle of forty-five degrees. By looking down into this mirror we see the object which it to be photographed, in the proper position, right-side up.

After focusing, the sensitized plate takes the place of the ground glass, as in the modern camera, and the side of the plate holder toward the lens is released by loosening a button, and allowed to drop down and rest on the bottom of the camera, thereby uncovering the plate.

Everything is now in readiness for the exposure, which is done by opening the metal cover of the lens.

M. Daguerre, in his original communication to the French Academy, stated that the time of exposure varied, at Paris, from three to thirty minutes, according to the season of the year and the time of day.

After exposure, the plate holder is closed by means of a strap, which projects through a slot in the holder, and withdrawn from the camera with its contents.

The plate is then ready for the third operation. It is placed into the box arranged for development, and exposed to the vapor of mercury.

The small metal dish at the bottom of the box containing the mercury is heated by a spirit lamp.

When the temperature reaches 140° F. the lamp is withdrawn and in a short time development begins; it can be observed through the glass in the box.

When the temperature of the mercury has fallen to 113° F. the plate is finished and ready to be fixed. This is accomplished by dipping it into a weak solution of hyposulphite of soda. It is afterwards washed in clean water and then put under glass for permanent preservation.

During the sixty-eight years that have passed, many improvements have been made in camera accessories; devices for focusing

and adjusting, diaphragms and shutters, plate-holders and lenses; the design of the camera remains the same excepting that bellows have been substituted for the telescopic arrangement.

On the other hand, rapid strides have been made in the processes connected with picture-making, and the daguerreotype was in a short time succeeded by the many modifications, among the earlier being the ambrotypes and the opalotypes.

Much of the early history of photography in Philadelphia has been forgotten, and only a bare mention of the facts can be found in the works of reference.

It is to be hoped that a complete sketch may soon be written and that the names of the more recent investigators, who have labored so diligently, may be permanently recorded.

REFERENCES.

The Daguerreotype Explained by A. D. B. (Alexander Dallas Bache). J. F. I., 28, 209.

Daguerre's Photography, J. F. I., 28, 286.

Practical Description of the Process Called the Daguerreotype * * * by Daguerre. Translated for the Journal of the Franklin Institute by John F. Frazer. J. F. I., 28, 303.

Early Daguerreotype Apparatus, by Samuel Sartain, Journal of the Photographic Society of Philadelphia, 8, 33.

History of Philadelphia, Scharf & Westcott, 3, 2326.

Book Notices.

PUBLICATIONS RECEIVED.

The Spline Milling Machine, manufactured by the Pratt & Whitney Company, Hartford, Conn. Unpaged, illustrated, 4to. Hartford, Conn., 1908.

Structural Timber, by W. K. Hatt, Civil Engineer, Forest Service U. S. Department of Agriculture. Professor Civil Engineering, Purdue University. Read before the Western Railway Club, March, 1908. 28 pages, illustrated, 8vo.

U. S. Department of Agriculture, Forest Service—

Extent and Importance of the White Pine Blight. By S. T. Dana. 4 pages, 8vo. Washington, Gov't Printing Office, 1908.

Circular 138. Suggestions to Woodlot Owners in the Ohio Valley Region. By Samuel J. Record. 15 pages, 8vo. Washington, Gov't Printing Office, 1908.

Circular 141. Wood Paving in the United States. By C. L. Hill. 24 pages, illustrated, 8vo. Washington, Gov't Printing Office, 1908.

Circular 142. Tests of Vehicle and Implement Woods. By H. B.

Holroyd and H. S. Betts. 29 pages, illustrations, 8vo. Washington, Gov't Printing Office, 1908.

Circular 147. Progress in Chestnut Pole Preservation. By Howard F. Weiss. 14 pages, 8vo. Washington Gov't Printing Office, 1908.

University of Illinois Bulletin, Vol. 5, No. 7, October 21, 1907. Municipal Water Supplies of Illinois. By Edward Bartow. 123 pages, map, 8vo. Urbana, University, n. d.

Zoology Bulletin of the Division of Zoology of the Pennsylvania Department of Agriculture, May 1, 1908; June 1, 1908. Harrisburg, State Printers, 1908.

Paper and Pulp Investigation Hearings. Preliminary Report, No. 25. 20 pages, 8vo. Washington, Gov't Printing Office, 1908.

Pennsylavnia State College Bulletin, April, 1908. Catalogue of the School of Agriculture and Experiment Station. Announcements, 1908-1909. 63 pages, 8vo. State College, 1908.

Stahl und Eisen. Gesammt—Inhaltsverzeichnis der Jahrgaenge 1-26 (1881-1906). Im Auftrage des Vereins Deutscher Eisenhuettenleute. Bearbeitet von Franz Liebetanz, Duesseldorf. Verlag Stahleisen (m. b. H.) 8vo. 370 pages. Half leather.

Every student and investigator in the field of metallurgy, who has a working knowledge of the German language is familiar with that excellent publication, "Stahl und Eisen," which has appeared regularly during the past twenty-seven years, under the direction of the Society of German Iron Manufacturers. In the volumes may be found the records of progress in all the fields of metallurgy, though the iron and steel industries receive special attention. The set is a store-house of information for the metallurgical worker. To make the series still more valuable it is now supplied with an index which covers the subjects, titles and authors of all the volumes from the beginning, in 1881, to the end of 1906. The preparation of this index was undertaken by Mr. Liebetanz, and the work seems to have been done carefully. The publication of this index will make the file of "Stahl und Eisen" more useful for reference than it has been heretofore.

A. R.

Erratum.

April number, 1908, Vol. CLXV, page 262, tenth line from the bottom, after the figures "1855-68," insert following the comma, "58 respectively;" page 297, fourth line from top, for "1868-69" read "1866-69."

JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 5 83RD YEAR NOVEMBER, 1908

History, Manufacture and Analysis of Maple Products.

By Albert P. Sy, Ph.D.

(*Continued from vol. clxvi, p. 280.*)

SPECIFIC GRAVITY. DENSITY.

The standard density of maple sirup is 1.325 or 36° Baumé; this corresponds to a sirup, a gallon of which will weigh eleven pounds, and which has a boiling point of 103.9 °C. (219°F.). Sirups are found which are thinner and others thicker than this. Some analysts use an ordinary sp. gr. hydrometer for taking density, the writer prefers a picnometer bottle with a thermometer stopper. The use of a picnometer requires careful manipulation and will then give more accurate results than any other apparatus. The writer proceeds as follows: The sirup is carefully poured into a small, lipped Erlenmeyer flask and cooled under the tap or in ice water until it is about 1° colder than the temperature at which sp. gr. is to be taken (15.5°C.); the sirup is then poured carefully into the picnometer (the 25 c.c. size) which is also

cooled to about 15.5°; the thermometer is then inserted, the whole washed and wiped and the cap put on when thermometer shows 15.5°C.. Care must be taken not to agitate the sirup at any time since it becomes filled with small bubbles which separate only very slowly. Some analysts cool the sirup to 10 or 12° and place it in picnometer, insert the thermometer and wait until the latter shows 15.5°. This will not give accurate results, since the picnometer and outer layer of sirup are considerably warmer than 15.5° when the thermometer shows this temperature. The specific gravity may be used for estimating "total solids" by using the table* prepared for this purpose. Specific gravity multiplied by 8.32 gives the weight of a gallon of sirup. Hortvet found the average sp. gr. of twenty-two samples of pure maple sirup to be 1.3166, corresponding to a weight of 10.95 pounds per gallon.

TOTAL SOLIDS. MOISTURE.

Total solids may be determined directly or indirectly. The direct determination consists in drying the sample (about three grams) in a flat-bottomed dish, at temperature of boiling water. Hortvet† dries for eight hours, or to constant weight. This direct method has the objection of all methods where sugar or saccharine substances are dried at 100°; the sugars undergo chemical changes during the long period of drying necessary to expel all water; the long time, and repeated weighings required make the process tedious.

The writer much prefers to use the indirect method, in which the solids are estimated from the density, using a table. For sirups, the method of obtaining density has been described under "Specific Gravity:" For sugars, a weighed amount, about 25 g., is placed in a 100 c.c. flask, dissolved and made up with water to mark and specific gravity of this solution taken. The total soluble solids can then be calculated from the following formula:

$$\text{Soluble solids} = \frac{100 \times \text{sp. gr.} \times \%\ \text{solids corresponds to sp. gr.}}{\text{weight taken.}}$$

*Bul. 107, Bureau of Chem. U. S. Dept. Agr., p. 66.

†Jour. Am. Chem. Soc., 26, p. 1527.

The amount of total solids in a maple product, taken by itself, has no significance, except that it shows how thick or thin a sirup is, or how much water there is in a sugar. Hortvet found an average of 66.45% of total solids in twenty-two samples of pure maple sirup, using the direct drying method. For nineteen samples of pure sugar the average was 90.70% total solids. The relation of total solids to sucrose will be discussed later,

PROTEIN.

The protein (nitrogen) determination is usually not made in an analysis of a maple product. Since, however, all pure products have a certain percentage of protein, the addition of adulterants containing little or no protein (glucose, cane sugar) causes a corresponding lowering of this percentage. Hortvet* found that pure sirups contain from 0.223 to 0.334% protein, while in sugar he found from 0.32 to 0.816%. Wiley† found an average of 0.0143% protein in the sap of 1500 trees; since in making sirup from a 3% sap, it must be concentrated about twenty-two times, the protein would become 0.227% in the resulting sirup. Wiley also found some trees producing sap containing 0.0242% protein; this would produce a sirup containing 0.532% protein. Some protein is lost during evaporation, since it coagulates and is removed by skimming.

The protein is determined by the Gunning nitrogen process, using about five grams of sirup or sugar. The per cent. of nitrogen found, multiplied by 6.25 gives the protein.

MALIC ACID.

One of the most important non-sugar constituents of maple sap is malic acid. It is always present in genuine maple products. It exists, as was pointed out under "Physiology," partly as free

*Jour. Am. Ch. Soc., 1904, p. 1539.

†Bul. 5, Div. of Chem. Dept. Agr., p. 210.

but mainly as combined malic acid,* as calcium, potassium and sodium malates.† The amount of total malic acid in a maple product varies considerably; one cause is that trees in different localities produce sap with different amounts of malic acid; the main cause, however, lies in the fact that as the sap is concentrated, the malic acid is separated as the calcium salt ("niter") and is more or less completely removed, part of course remaining in solution in the sirup. Jones‡ reports for sirups an average of 0.53% with 0.41% and 0.72% as minimum and maximum (thirty-five samples); for sugars the average is 0.75%, minimum 0.65%, maximum 0.84%. Hortvet§ using the same method of analysis obtained considerably higher results; sirups, averaging 1.08%, minimum 0.84%. maximum 1.28% (seventeen samples) for sugars: average 1.28%, minimum 0.98%, maximum 1.67%.

Since both analysts used the same method, this difference in results can be explained partly by a difference in the products analyzed; Jones' analyses were on Vermont products, while Hortvet analyzed mostly Minnesota, New York, Pennsylvania and Ohio products. Another cause for difference in results lies in difference in manipulation of the same method, *i. e.*, by different analysts. Hortvet,¶ as associate referee on saccharine products for the Association of Off. Agr. Chemists, reports malic acid in two maple sirups and two sugars, the results being obtained by seven different chemists, all using the same method:**

	Average.	Minimum.	Maximum.
No. 1, Ohio sirup	0.63%	0.30%	0.93%
No. 2, Vermont sirup	0.76	0.31	1.26
No. 3, Vermont sugar	0.93	0.61	1.21
No. 4, Vermont sugar	0.94	0.71	1.23

These differences are enormous and proved that the method used is unreliable.†† Jones,‡‡ who was associate referee the fol-

*Free and combined malic acid are found in some plants, notably in Rhûs glabra, smooth sumac.

†Jones, 18th An. Report Ver. Station, p. 316.

‡Ibid, p. 317.

§Jour. Am. Chem. Soc., 1904, p. 1528.

¶Proceed. 22d An. Con. A. O. A. C., 1905, p. 42.

**Cir. 23, Bur. Chem.

††The disturbing factor was NH_4OH; the precipitation is made from an ammoriacal solution.

‡‡Proceed. 23d An. Con. of A. O. A. C., 1906, p. 14.

lowing year, took up this same subject. Three samples of sugar were sent out to different chemists, thirteen of whom reported results:

	Average.	Minimum.	Maximum.
No. 1—40% maple + 60% cane sugar	0.08%	0.03%	0.13%
No. 2—40% maple + 60% lt. brown sugar	0.08	0.04	0.13
No. 3—Pure maple sugar	0.39	0.22	0.64

The writer's results on the above samples were 0.03%, 0.05%, and 0.29%, respectively.

These results are still far from satisfactory and the method could not be used for the determination of actual amounts of malic acid. As will be seen from these figures, the method can however. be used for differentiating between pure and adulterated samples. (Several of the analysts reported results by this method, using ammonia, *i e.,* precipitating from an ammonical solution; in each case this gave much higher results.) The method as used and reported on was to precipitate the malic acid with $CaCl_2$ (10% sol.), from neutral solution, add alcohol, let stand, filter, wash with alcohol, dry, ignite, titrate $CaCO_3$, using methyl orange.

The method for determining the malic acid value of maple products adopted provisionally by the Official Association of Agricultural Chemists* is as follows: Weigh 6.7 grams of the sample into a 200 c.c. beaker and add water to make a volume of 20 c.c.. Make the solution slightly alkaline with ammonium hydroxide, add 1 c.c. of a 10% solution of calcium chlorid, then add 60 c.c. of 95% alcohol. Cover the beaker with a watch glass, heat for one-half hour on a water bath, then turn off the flame and allow the beaker to stand over night. Filter through good quality filter paper, wash the precipitate with hot 75% alcohol until free from chlorids, then dry and ignite. Add from 15 to 20 c.c. of tenth-normal hydrochloric acid to the ignited residue, thoroughly dissolve the lime by heating carefully to just below boiling, cool and titrate the excess of HCl with tenth-normal Na OH, using methyl orange. One-tenth of the number of cubic centimeter of acid neutralized by the ignited residue expresses the malic acid value.

---

*Bul. 107, Bur Chem., U. S. Dept. Agr., p. 73.

ASH.

The work of Jones* on the ash of maple products was a valuable addition to the methods now in use for detecting adulteration. Maple products are never more than partially refined; if they were refined to the same extent as cane sugar is, then they would lose the flavor—maple flavor— to which they owe their value. Since glucose was readily detected by the polariscope, the "mixers" soon abandoned it and used cane sugar for adulterating maple products; here the polariscope is of no help, and until Jones' work on the ash and the work of others on "lead precipitate" became known, it was considered imposisble for a chemist to detect the adulteration. Cane sugar has practically no ash and its addition to maple products decreases the percentage of ash correspondingly. Commercial brown sugar sometimes contains about the same amount of ash as maple products, so that, if simply the percentage of ash were determined, the adulteration would not be detected. But brown sugar ash differs from maple ash in character, especially in its ratio of soluble to insoluble ash; an average of forty-eight results reported by Jones† gives total ash as 0.60%; soluble ash, 0.38% insoluble ash, 0.22%; brown sugars having about 1.00% of ash have only 0.10% insoluble ash.

Variations in the percentage of ash in maple products are due to a difference in soil where the trees grow, but mainly to a difference in manufacture. The amount of ash depends a great deal upon the amount of "niter" left in the sample; if a sugar is made by simply evaporating sap, without clarifying in any way, then the ash will be high. Since sugars are usually more or less incompletely clarified or filtered—sometimes not at all—it follows that the greatest variations as well as the highest percentages are to be expected in these. This the writer found to be the case, as will be seen from analyses reported. There is much less variation in ash percentage in clarified sirup. In order to obtain a better indication of purity of a maple product from its ash content, Jones‡ proposes to prepare all samples for analysis by subjecting them to a clarification in the laboratory. This he does by dis-

*17th An. Rpt. Ver. Station, p. 446; also, 18th An. Rpt., p. 315.
†18th An. Report, Ver. Station, p. 317.
‡18th An. Report, Ver. Station, p. 327.

solving 4 grams of sirup or sugar in 5 to 10 c.c. hot water for sirups, 15 to 20 c.c. for sugars; boil carefully on an asbestos board, stir and boil until an accurate and delicate thermometer indicates 219°F. for a good or medium grade and 220°F. for a poorer grade of product. The sirup is then filtered hot through a dry, double S. & S. 597 filter without suction; pure maple usually filters quite readily. This brings all samples on a common basis of concentration and clarification and reduces the variations in percentage of ash (also malic acid and "lead precipitate") to a minimum. As is to be expected, this affects sugars more than sirups. Jones* found the following percentages of ash in sirups and sugars:

	Total ash.	Soluble ash.	Insoluble ash.
Average in original sirups	0.63	0.38	0.25
Average in filtered sirups	0.58	0.36	0.22
Average in original sugars	0.94	0.45	0.49
Average in filtered sugars	0.55	0.36	0.19

These results also show that there is a close agreement in the results of the filtered sirups and sugars.

As an average of forty-eight analyses of pure maple sirups Jones† found the following, the maximum and minimum being given also:

Sirups:	Total ash.	Soluble ash.	Insoluble ash.
Average	0.60	0.38	0.22
Maximum	0.86	0.47	0.51
Minimum	0.50	0.29	0.16

For forty-two *sugars* he found the following:

Average	0.91	0.48	0.43
Maximum	1.32	0.63	0.87
Minimum	0.64	0.36	0.20

Hortvet‡ found the following in pure products:

Sirups:			
Average	0.68	0.39	0.31
Maximum	1.01	0.49	0.55
Minimum	0.52	0.21	0.15

*Ibid, p. 320.
†18th An. Ver. Report, p. 317.
‡Jour. Am. Chem. Soc., 26, p. 1528.

Sugars:			
Average	0.91	0.45	0.51
Maximum	1.30	0.67	0.78
Minimum	0.65	0.33	0.32

The results of the cöoperative analyses by thirteen chemists on the same sample of pure sugar are as follows:*

Sugars:			
Average	0.73	0.44	0.29
Maximum	0.86	0.59	0.34
Minimum	0.61	0.32	0.22
Sy	0.74	0.46	0.28

Woodman† obtained the following percentages of ash in pure maple products:

Sirups:	Total ash.	Soluble ash.	Insoluble ash.
Average	0.62	0.38	0.24
Sugars:			
Average	1.02	0.52	0.50

Analyses by the writer of maple products known to be pure are as follows:

Sugars:

Sample No.	Total ash	Soluble ash.	Insoluble ash.
1	0.81%	0.42%	0.39%
2	0.71	0.58	0.13
3	1.22	0.70	0.52
4	0.71	0.44	0.27
5	0.62	0.40	0.22
6	0.63	0.45	0.18
7	0.79	0.57	0.22
8	0.90	0.47	0.43
9	0.82	0.42	0.40
10	0.73	0.55	0.18
Average	0.79	0.50	0.29

Sirups:

Sample No.	Total ash.	Soluble ash.	Insoluble ash.
15	0.48	0.32	0.16
16	0.76	0.45	0.31
17	0.64	0.38	0.26
18	0.47	0.34	0.13
22	0.50	0.29	0.21

*Proceed. 23d An. Convention, U. O. A. C., p. 17.
†Technological Quarterly, 18, p. 150.

24	0.42	0.26	0.16
26	0.70	0.37	0.33
27	0.71	0.33	0.38
28	0.68	0.41	0.27
31	0.50	0.35	0.15
33	0.40	0.32	0.08
36	0.61	0.38	0.23
39	0.55	0.32	0.23
40	0.65	0.41	0.24
49	0.54	0.35	0.19
50	0.72	0.41	0.31
Average	0.58	0.35	0.23

In addition to the quantities of soluble and insoluble ash, the character of the ash is also a valuable indication. This applies especially to the alkalinity of the soluble and insoluble ash. Jones reports * the following figures for pure products; the results being expressed as cubic centimeters of tenth-normal HCl required to neutralize the ash from one gram of sample, using methyl orange indicator:

	Alkalin. Sol. ash.	Alkalin. Insol. ash.
Sirups (48).		
Average	0.51%	0.54%
Maximum	0.66	0.94
Minimum	0.30	0.36
Sugars (43).		
Average	0.61	0.91
Maximum	0.80	1.72
Minimum	0.40	0.55

The pure sugar analyzed by thirteen chemists in the cöoperative work to which reference has previously been made gave these results:

	Alkalin. Solvent ash.	Alkalin. Insolvent ash.
Average	0.53%	0.70%
Maximum	0.66	0.88
Minimum	0.36	0.60
Sy	0.60	0.60

Hortvet† found the following:

Sirups (13).		
Average	0.52	0.61
Maximum	0.66	0.85
Minimum	0.38	0.31

*18th An. Report Ver. Sta., p. 317-318.

†Jour. Am. Chem. Soc., 26, p. 1528.

Sugars (11).		
Average	0.66	1.06
Maximum	0.95	1.46
Minimum	0.55	0.66

The writer found the following alkalinities in the ash from pure products:

Sugars:

Sample No.	Alkalin. Soluble ash.	Alkalin. Insoluble ash
1	0.59c.c.	0.20c.c.
2	0.64	0.42
3	0.90	0.81
4	0.61	0.68
5	0.53	0.68
6	0.57	0.74
7	0.69	0.74
8	0.64	0.93
9	0.61	0.82
10	0.57	0.53
Average	0.64	0.66

Sirups:

Sample No.	Alkalin. Soluble ash.	Alkalin. Insoluble ash.
15	0.19	0.39
16	0.42	0.46
17	0.38	0.38
18	0.17	0.39
22	0.24	0.40
24	0.17	0.39
26	0.15	0.74
27	0.24	0.72
28	0.28	0.64
31	0.17	0.41
33	0.20	0.33
36	0.21	0.46
39	0.18	0.56
40	0.22	0.46
49	0.08	0.45
50	0.36	0.46
Average	0.23	0.48

Hortvet reports* the following analyses of ash of pure maple products:

*Jour. Am. Chem. Soc., 26, p. 1541.

	Silica and Sand	CO_2	CaO	MgO	Mn_3O_4	K_2O	Na_2O	SO_3	P_2O_5	Cl
Minnesota Sirup...	2.25	30.86	18.60	4.65	0.75	31 58	6.86	2.31	1.64	.09
Penn Sirup.....	2.17	28.70	20.35	4.16	2.22	30.87	4.01	2.42	4.67	.....
Vir. Sugar.....	9.77	30.22	23.05	2.54	0.45	28.37	2.84	1.15	1.18	trace
Vir. Sugar	4.48	30.79	20.62	3.75	0.50	33.06	3.56	1.77	1 24	trace

In most cases the ash of a pure maple product has a distinct green color, sometimes very faint and sometimes an intense green; in some instances the writer has found no green color in ash of pure products. This color is best observed after fusing the ash. Hortvet reports* green colored ash for Minnesota maple products as an almost constant indication. The writer has analyzed a number of pure New York State products that showed no green ash; some of these developed the green color after fusing. Jones† reports the presence of manganese in maple ash, but does not mention or discuss the green colored ash. As will be seen from the ash analyses above mentioned, manganese is present in quite considerable quantities, not merely as traces.

Directions for determination of manganese are given in Circular 23, Bur. of Chemistry, Department of Agriculture, p. 6. The writer found 0.55% of manganese (as Mn_3O_4) in the ash of a pure maple sugar, the ash of which was 0.81% and quite green in color. This green color is no doubt due to the changing of the manganese into manganates; the potassium and sodium, and the calcium salts of the organic acids on ignition of the sample are converted into the corresponding carbonates, and the latter react with the manganese on fusion, and manganates are produced. On dissolving a number of green ashes in HCl, the writer observed a change in color to a permanganate pink, indicating a change from manganates to permanganates.

Organic salts of manganese, on ignition, are converted into MnO mostly; when this oxid is heated in the air with sodium or potassium carbonate or hydroxid, oxygen is absorbed and sodium or potassium manganates are formed as follows:

$$MnO + Na_2CO_3 + O_2 = Na_2MnO_4 + CO_2.$$
$$MnO + K_2CO_3 + O_2 = K_2MnO_4 + CO_2.$$

*Ibid.

†17th An. Report Ver. Station, p. 456.

With hydroxid, the reaction is as follows:

$$MnO + 2\,KOH + O_2 = K_2\,MnO_4 + H_2O.$$

The alkali manganates are intensely green in color, quite soluble in water, but are decomposed by excess of water or by acids, forming permanganates with a characteristic red or pink color; MnO_2 (brown, insoluble) is also formed:

$$3\,K_2\,MnO_4 + 2\,H_2O = 2\,K\,MnO_2 + MnO_2 + 4\,KOH.$$

The solubilities and color changes the writer has repeatedly observed in the ash from pure maple products.

It has been supposed that probably all or at least most of the manganese found in maple ash is derived from the vessels used in collecting and evaporating the sap. To get information on this point, the writer evaporated and ashed several samples of sap that had never been in contact with anything except a jug and a platinum dish; the ashes showed a typical green maple-ash color.

As before stated, the ash of pure maple products is not always green. The writer has analyzed a number of pure samples that gave no green ash. This was the case mostly in old sirups, and it is quite probable that the manganese compounds were removed when the sirups were made, especially those made from maple sugar by dissolving and filtering the latter. No doubt some soils contain so little manganese that not enough would find its way into the sap to produce a green ash. This is indicated by the fact that samples from certain districts produce a much greener ash than others.

Maple products are the only saccharine substances with a manganese content sufficiently high to produce a green ash, and a green ash is an indication of at least some maple product in the sample. The writer has repeatedly observed a green ash in black peppers; this appears to be due also to manganese.* König† reports a green ash from Rio coffee.

The writer makes the following ash determinations on maple products.

1. Total ash, as % on original sample.
2. Soluble ash as % on original sample.

---

*The writer expects to determine percentage of Mn in several samples of pepper now on hand.

†Untersuchung, Nahrungs ü. Genussmittel, I, p. 987.

3. Insoluble ash, as % on original sample.
4. Alkalinity of soluble ash, expressed in "number of c.c. of tenth-normal acid necessary to neutralize ash from one gram of original sample (methyl orange)."
5. Alkalinity of insoluble ash, as above.

1. *Total ash:*

Weigh ten grams of sample in a tared flat-bottomed platinum dish, heat on asbestos gauze with bunsen burner; when charred, transfer to a muffle furnace and heat until ash is white or until the residue no longer glows—do not fuse after ash is white. Cool and weigh.

2. *Soluble ash:*

Total ash minus insoluble ash.

3. *Insoluble ash:*

Add water to residue from "total ash," heat nearly to boiling, filter (ash free filter), wash with hot water till filtrate equals about 60 c.c. Return filter paper and residue to platinum dish, dry, ignite and weigh.

4. *Alkalinity of soluble ash:*

Allow filtrate from "insoluble ash" to cool, add methyl orange and titrate with tenth-normal acid.

5. *Alkalinity of insoluble ash:*

The insoluble ash is treated with an excess (15 c.c.) of tenth-normal acid (HCl), heat to boiling point on asbestos gauze, cool, add methyl orange, and titrate excess of acid with tenth-normal alkali. (NaOH).

When igniting pure maple products for "total ash" the writer observed that there was always considerably more frothing and tendency to boil over than in adulterated samples, some of the latter showing scarcely any frothing or bubbling. This led the writer to make further experiments, and resulted in the "foam test," to be described later.

SUGARS

Under this heading there will be considered the various saccharine matters that may be present in a pure or adulterated product.

Sucrose (cane sugar) $C_{12}H_{22}O_{11}$.

As was stated in connection with the physiology of maple sap,

the principal sugar contained in it is sucrose, which is chemically identical with cane sugar. A determination of sucrose alone would not detect adulteration of a maple product with cane sugar. The amount of sucrose in maple products varies according to the method of manufacture used,—the degree of concentration and extent of inversion of sucrose. Hortvet* reports the following:

	Sucrose.	Total solids	Difference.
Sirups (22) average.....	60.90	66.45	5.55
Sugars (19) average..... ...	84.77	90.70	5.93

Sirups reported in New Hampshire Station Bulletin 25 are as follows:

	Sucrose.	Total solids	Difference.
Sirups (8) average.....	64.77	68.00	3.23

These, however, were freshly and carefully prepared and contain only about (average) .20% reducing sugar; this leaves a difference of 3.03% solids not sugar. Hortvet's sirups contained (average) 2.83% reducing sugar, leaving 2.72% solids not sugar.

The writer's results on pure products are as follows:

	Sucrose.	Total solids	Difference.
Sirups (16) average.....	61.39	67.05	5.66
Sugars (10) average.....	88.87	96.65	7.78

These data show a difference of 5.66% for sirups and 7.78% for sugars between the total solids and the sucrose; this difference is made up of invert or reducing sugar and "solids not sugar." It follows that in a pure maple product there is always this considerable difference and is not found in cane sugar or products adulterated with cane sugar, decreasing in the latter as the amount of cane sugar added increases. To be sure the presence of glucose increases this difference, but this adulteration is readily detected, as will be seen later.

Invert sugar, (reducing sugar) sometimes erroneously called "glucose." This is present in the sap before evaporation, and the amount increases, relatively, as the sap is evaporated, the sucrose being inverted by the heat in the presence of the salts in the sap; further inversion may be caused later by enzyms and micro-organ-

*Jour. Am. Chem. Soc., 26, p. 1528.

isms*. As the sap season advances the amount of invert sugar increases. Invert sugar is a mixture of equal quantities of dextrose and levulose, one molecule of sucrose, $C_{12}H_{22}O_{11}$, on inversion forming two molecules of $C_6H_{12}O_6$. In many analytical reports this invert sugar is given as "reducing sugar," since it reduces Fehling's solution while sucrose does not. The amount of reducing or invert sugar in maple products varies considerably, from less than one per cent. to more than ten per cent. have been found. Hortvet† found the following percentages of invert sugar:

	Average.	Maximum.	Minimum.
Sirups (22)	2.83	9.17	0.60
Sugars (19)	3.27	8.37	1.16
The writer's results are as follows:			
Sirups (13)	2.71	4.20	1.34
Sugars (9)	3.27	8.05	1.14

Sample No. 3, a very dark, almost black, sugar, gave 14.14% reducing sugar and is not included in the above.

Sometimes analysts, especially those who analyze maple products only occasionally, fall into the error of reporting reducing sugar as glucose; in fact, unles polariscope readings are also used, especially at 87°C. after inversion, it would in most cases be impossible for the "occasional" analyst to differentiate between invert sugar and added glucose. On the other hand, although it is true that a pure maple product always contains reducing sugar, its presence must not be interpreted to mean that the product is pure, since added cane-sugar syrup on boiling also produces invert sugar. Again, the entire absence of, or only traces of invert sugar indicates that the product is not pure maple.

To study the effect of heat on a maple sirup, Hortvet‡ boiled a sample for forty-five hours, making analyses at five hours' intervals. The loss in "total sugar" between the sixth and seventh periods was caused by fermentation, three months having elapsed between these periods.

---

*According to Geerlings (Chem. Centbl., 1898, p. 711) cane sugar in the presence of glucose is inverted by neutral salts; all mono saccharids can cause this inversion. This may account for the high invert sugar found in samples adulterated with glucose.

†Jour. Am. Chem. Soc., 26, p. 1528.

‡Jour. Am. Chem. Soc., 26, p. 1539.

Time Hours	Polarization		Sucrose %	Reducing Sugar %	Total Sugar %	Sucrose in Total Sugar %	Reducing Sugar in Total Sugar %
	Direct	Invert.					
	original	sample	40.33	1.67	42.00	96.01	3.99
5	+ 38.0	— 14.5	39.47	2.35	41.82	94.31	5.69
1	+ 36 0	— 13.6	37.15	3.60	40.75	91.16	8.84
15	+ 34.0	— 12.2	34.73	6.04	40.77	85.18	14.82
20	+ 26.9	— 11.8	29.10	11.12	40.32	74.07	25.93
25	+ 20.2	— 11.2	23.43	17.09	40.52	57.82	42.18
30	+ 14.0	— 11.2	18.82	21.44	40.26	46.77	53.23
35	+ 2.5	— 11.2	10.76	26 75	37.51	28.69	71.31
40	— 4.5	— 13.1	6.57	30.89	37.46	17.54	82.46
45	— 9.0	— 10.2	0 28	37.25	37.53	0 78	99 22

Invert sugar and glucose both reduce Fehling's solution, but can be differentiated by means of a polariscope; invert sugar at 87°C. gives a 0 reading on the Soliel-Ventzke sugar scale, while glucose, which is largely dextrose, gives a *plus* reading according to the amount present. Although invert sugar consists of equal amounts of a right and a left rotating sugar, yet at ordinary temperatures the effect of the levulose is much greater than that of the dextrose, and the reading is *minus;* at 87°C. they have equal rotating power and the reading is 0.

GLUCOSE.

This is not a normal constituent of maple products; it is considered here because it is still occasionally used as an adulterant, however, not nearly as much as formerly, since it can readily be detected. Since both glucose and invert sugar reduce Fehling's solution, care must be exercised not to confound these two when only chemical methods of analysis are employed. According to Leach* the grade of glucose usually used for adulterating purposes is the 42° Bé variety; this polarizes at about 175° (max.). Since, in a maple product after inversion, both the original invert sugar and that produced from the sucrose read 0° at 87°C., the presence of glucose is indicated by a *plus* reading.

*"Food Inspection and Analysis," p. 505.

ANALYTICAL METHODS FOR SUGARS.

There are two classes of methods for the determination of sugars, chemical and polariscopic.

SUCROSE. (a) *Chemical Method:** Determine the reducing sugars with Fehling's solution (copper oxide method) and calculate to "invert sugar," using the tables given in Bulletin 107. Then determine reducing sugar after inverting sample and calculate this also to invert sugar. Subtract invert sugar before inversion from that after inversion; the difference is invert sugar formed from sucrose; this difference multiplied by 0.95 gives sucrose. The writer prefers the Reduction method and tables given by Munsen and Walker.†

(b) *Polariscope Method.*

A normal weight (26.048) of the sample is dissolved in water, clarified with subacetate of lead, diluted to 100 c.c. and filtered. The filtrate is polarized at 20°C. in a 200 m.m. tube; this gives "direct" reading, or reading "before inversion." For inversion take about 60 c.c. of the filtrate, add enough anhydrons $Na_2CO_3 + Na_2SO_4$ (1.10) to remove excess of subacetate of lead, and filter; of the clear filtrate take 50 c.c., place in a 100 c.c. flask, add 25 c.c. water, 5 c.c. HCl (38.8%); mix thoroughly and place in water bath of 70°C. so that the solution reaches 69°C. in about two and a-half to three minutes; keep at 69°C. for seven to seven and a-half minutes; remove, cool rapidly to 20°C. and dilute to 100 c.c.; polarize at 20°C. in a 200 m.m. tube; this multiplied by two gives "invert" reading or "reading after inversion." From the direct and invert readings, the sucrose is calculated as follows:

$$\text{Sucrose} = \frac{100\ (\text{direct} + \text{invert})}{142.66\ \dfrac{\text{temperature}}{2}}$$

INVERT SUGAR. This is determined by chemical methods; the writer uses Munsen and Walker's method. For ordinary maple products the preparation of the sample is made as follows: Weigh 25 g. into a 100 c.c. flask, add water to about 75 c.c.; add

*Bul. 107, Bur. Chem., Dept. Agr., p. 44.

†Jour. Am. Chem. Soc., 28, p. 663.

Bul. 107, p. 40.

2 c.c. lead subacetate and make up to 100 c.c.; filter, remove excess of lead in solution with adhydrous $Na_2CO_3 + Na_2SO_4$ (1:10) and filter; of this filtrate take 20 c.c. and add to a mixture of 25 c.c. Fehling's solution, No. 1, and 25 c.c. Fehling's solution, No. 2, and 30 c.c. of water; heat this in a 400 c.c. beaker on an asbestos gauze so that this mixture begins to boil in four minutes; continue boiling exactly two minutes, keeping the beaker covered with a watch glass; filter the cuprous oxid at once in a tared Gooch packed with asbestos, using suction; wash thoroughly with water at 60°C., then with 10 c.c. alcohol and 10 c.c. ether; dry for thirty minutes in water oven at 100°C., cool and weigh as cuprous oxid. From the tables find the corresponding amount of sugar. In case of high invert sugar, less than 20 c.c. of the solution must be taken; the amount of invert sugar in the amount taken should not exceed 250 m.g.

GLUCOSE, (a) *Chemical Methods.* These are usually only qualitative, and in most cases unsatisfactory.

(b) *Polariscopic Method.* A high direct reading is an indication of the presence of glucose, since the reading for a normal weight of 42° Bé glucose is about 175° (max.). When glucose is present, the invert reading is usually *plus.* The best quantitative indication is obtained making a reading at 87°C. on the solution prepared for "invert reading," as above described. This reading at 87° is done in a 200 m.m. all-metal, inside gold plated, jacketed tube; hot water is passed through the jacket until the thermometer in the solution to be polarized shows 87°C., at which temperature the reading is made. Since there is no satisfactory form of apparatus on the market for this purpose, and as the writer had to make a great many readings at 87°, the following arrangement (here described for the first time) was used, shown in Plate 15: A form of instantaneous water heater shown in the plate (made by the Buffalo Dental Mfg. Co.) was connected with the polariscope tube, PT in position; HC contains the heating coil; G is the gas supply for the large burner under the coil; CW is the cold water supply, HW is the hot water tube; WW is the overflow from the tube; T the thermometer which passes into the solution to be polarized. GWV shows a combination valve for turning on both water and gas at the same time; at P there is a pilot light. The valves at G and at CW are so regulated that the water passing into the polariscope tube will heat its contents

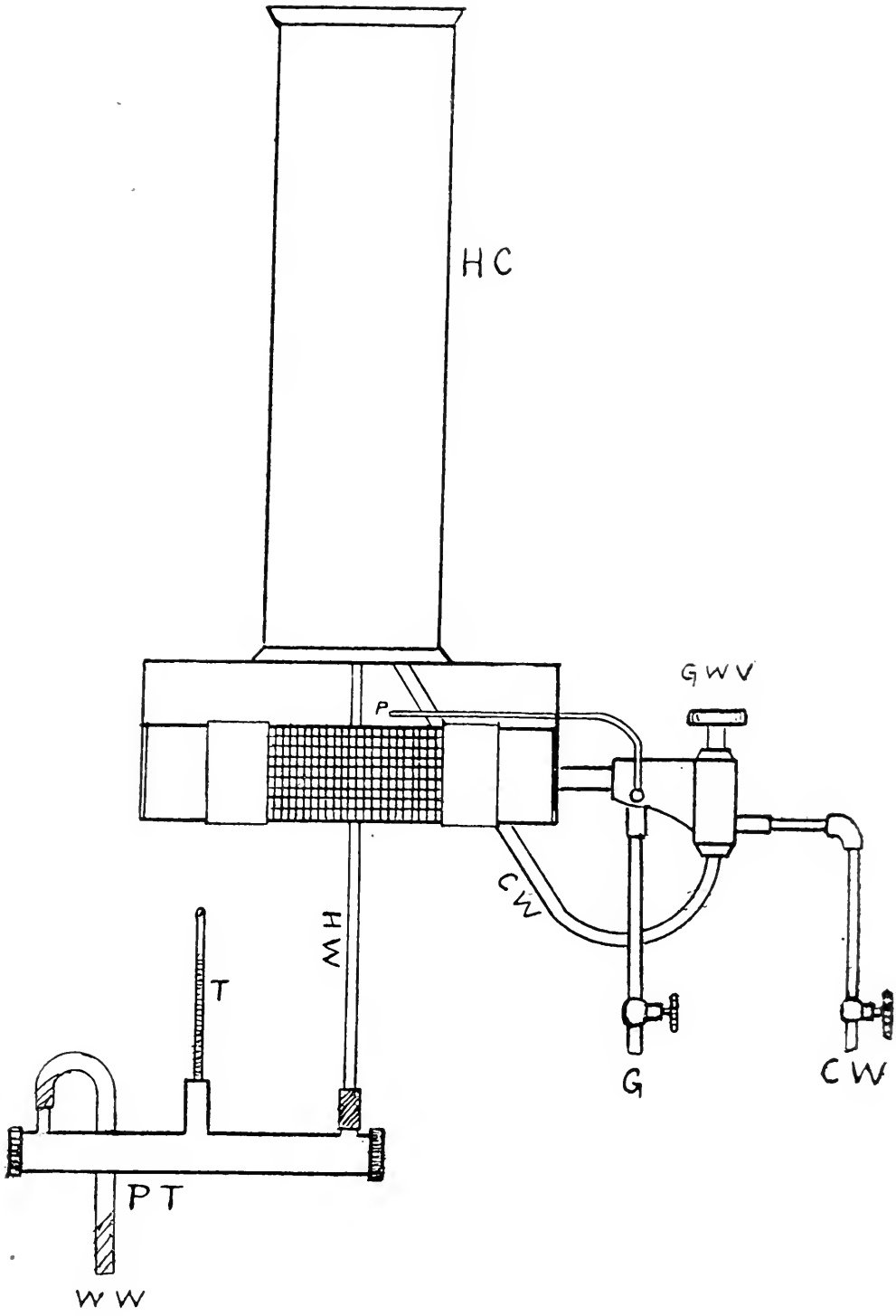


Plate 15. Arrangement for polariscopic readngs at 87° c.

to 87° C; when the water supply is cold, in winter, the adjusting of gas and water requires considerable care and experience; it was found necessary to add a second valve on the gas supply pipe G, this second valve being used to shut off most of the gas when starting successive heatings, since the hot water left in the heater from a previous heating is sometimes converted into steam when the full amount of gas is turned on with the valve at GWV.

This arrangement gave excellent satisfaction, both when single readings as well as a large number were to be made. The old arrangement of heating water in a tank by means of a burner and siphoning or allowing it to flow into the polariscope tube is very slow, and often has to be interrupted in the middle of a reading.

When glucose is present in a maple product the direct reading will be higher than the sucrose (clerget) according to the amount of glucose. Leach found 175° as the maximum polarization of a normal weight of commercial 42° Bé glucose, and uses the following formula for getting the approximate percentage of glucose present:

$$\text{Glucose} = \frac{(\text{direct reading.} - \text{Sucrose (clerget)}\ 100}{175}$$

This gives the percentage of glucose expressed in terms of 175° glucose.

It has been shown that a normal (polariscopic) solution of glucose gives a lower reading at 87° than at 20°; also that after inversion, glucose is very hard to read at 87°, since it changes rapidly. This must be taken into account when sirups or sugars containing large amounts of glucose are analyzed. Leach* proceeds as follows: Obtain direct reading as usual. For invert reading start with a separate half-normal weight, invert, neutralize with NaOH, clarify, make to 100 c.c, filter, and make reading at 20° and also at 87°. Since a normal glucose solution at 87° after inversion and neutralization reads about 93% of the direct polarization at ordinary temperature, the reading after inversion and at 87° must be multiplied by 0.93 to get the true reading; multiplying this by 100 and dividing by 163 ($175 \times 0.93 = 162.7$) will give the percentage of glucose, expressed in terms of "175° glucose."

*"Food Inspection and Analysis," p. 514.

Formula:

$$\text{Per cent of } 175^\circ \text{ Glucose} = \frac{(\text{Read. at } 87)\ 93.}{163}$$

LEAD SUBACETATE PRECIPITATE

The addition to maple products of lead subacetate and a qualitative and quantitative study of the resulting precipitate constitutes the most important test to-day in use. Results by this method began to be published about five years ago; the more important modifications will be discussed in the following: Lead subacetate when added to a maple product will precipitate the malic and other organic acids and their salts as well as sulfates, chlorids, carbonates, coloring and other organic matter. That a large proportion is other than malic acid is shown by the fact that on heating this precipitate it does not melt, while lead malate melts quite readily The quantitative methods used determine one of the following:

(1) The bulk or volume of the precipitate.
(2) The weight of the precipitate.
(3) The amount of lead in the precipitate.
(4) The amount of malic and other acids combined with the lead.

JONES' METHOD*

In this method the volume of the precipitate is measured. The process is as follows: Five grams of sirup or sugar are weighed into a Purdy sediment tube and dissolved in 10 c.c. of water. Two c.c. of official† subacetate of lead are added, mixed, and the tube whirled in a Babcock machine for four minutes at a speed of 1400 revolutions per minute. The volume of the precipitate is then read on the scale. This will be from 1.5 to 3 c.c. for pure maple products. Cane sugar gives but a trace of precipitate while adulterated maple products usually give from 0.1 to 1.0 c.c. This

*17th An. Report Ver. Station, p. 454.
†Bul. 107, Bur. Chem. Dept. Agr., p. 40.

method, the author says, has its limitations, and was designed more especially as a factory test.

HORTVET'S METHOD.*

Working independently of Jones, Hortvet devised the following method, similar to that of Jones, the volume of the lead precipitate being measured. Hortvet devised his method after noticing the wide variation in the volumes of the precipitates formed when clarifying maple products with lead subacetate for making polariscope readings. The apparatus used is shown in Plate 16, the glass tube used having the appearance of an inverted Babcock milk test bottle. For making the test, 5 c.c. of sirup or 5 grams of sugar are put into the tube, 10 c.c. water added, mixed; now add 0.5 c.c. cream of alumina and 1.5 c.c. lead subacetate (official) shake and let stand about one hour. The tube is then placed in the centrifugal and run six minutes; if any material has not settled into the stem of the tube, it is loosened with a fine wire; the tube is whirled another six minutes. Make a blank determination, using water and the reagents; the reading of the blank subtracted from that of the sample gives volume of precipitate. In sirups, this should be divided by the specific gravity of the sample to reduce the reading to a five-gram basis.

The volume of the precipitate will vary the amount of whirling and will depend upon the radius of the centrifugal speed and time. Hortvet used a machine having a radius of 18.5 c.m. and ran it at a speed of 1600 revolutions per minute. In order to secure uniformity of results it is necessary that the same amount of force be used to produce the volume of the precipitate. The formula for centrifugal force is $\text{Force} = \frac{\text{mass} \times (\text{velocity})^2}{\text{radius}}$; calling mass equal to unity and solving for velocity we get

$$\textit{velocity} = \sqrt{\text{Force} \times \text{radius}}.$$

From this formula a numerical expression for "Force" can be computed, then having measured the "radius" for a given machine, the value of "velocity" and the required number of revolutions

*Jour. Am. Chem. Soc., 26, p. 1532.

Total length	15.2
Diameter (wide part)	3.0
Diameter (neck)	2.0

Stem graduated to 5 cc and tenths; 5 cc division line 5 mm below beginning of wide part.

Ground area on wide part for use in numbering. Made of pine or white wood.

The tube is provided with a holder having the following dimensions:

	Cm.
Length	7.7
Diameter	3.2 to 3.5
Diameter of center hole, to fit stem	1.3

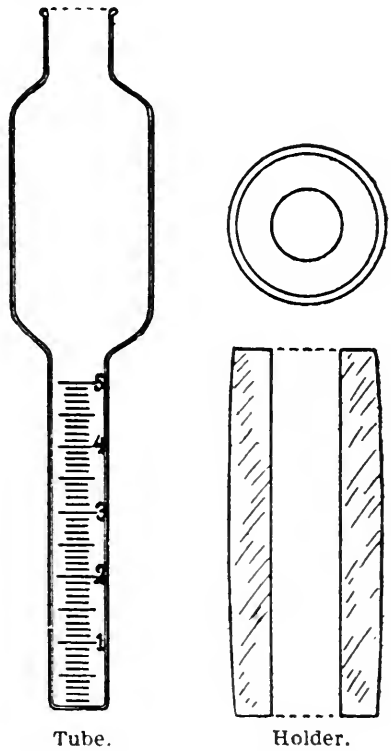


Plate 16. Hortvet tube and holder.

per minute can be found.* Adopting formula (7) in foot note,

$$N^1 = \sqrt{\frac{47,360,000}{r^1}}$$

which gives same force for centrifugal with radius r^1 as Hortvet's centrifugal.

The Hortvet precipitates (Hortvet numbers) vary as follows (twenty-two samples sirup, eighteen sugar, made by Hortvet):

	Minimum.	Maximum.	Average.
Sirups	0.94	1.82	1.26
Sugars	1.18	4.41	2.25

The writer has had difficulty with this method in obtaining concordant results; samples known to be pure giving very low results, and samples which by all other tests showed adulteration, gave as high as 1.3 Hortvet number; in some samples it is also quite difficult or impossible to get duplicates that agree. The results of cöoperative work by seven chemists† are as follows:

	Sirup 1.	Sirup 2.	Sugar 1. (All Pure)	Sugar 2.
Average	0.95	1.79	2.38	1.83
Maximum	2.15	2.50	3.70	2.90
Minimum	0.40	1.23	1.41	0.89

These differences are too great to consider this method sufficiently accurate for use by different operators on the same sam-

---

*Hortvet's method is found in Bul. 107, Bur. Chem., p. 72, as a provisional method. In this Bul. on p. 73, it is stated that the value for F (force) in the above formula becomes 138,378, using 18.5 for radius (r) and 1600 for velocity (v) and solving the formula $F = \frac{v^2}{r}$. The numerical expression 138,378 obtained for F by this formula is incorrect, since v is used for "revolutions per minute," whereas it should be used for peripheral velocity, which depends upon two variables, radius and revolutions per minute. The writer suggests the following formula: Since F^1 for any centrifuge used is to be the same as that used by Hortvet, we have—

$F = F^1$ - - (1) or

$\frac{M v^2}{r} = \frac{M^1 (v^1)^2}{r^1}$ - - (2) or

$\frac{v^2}{r} = \frac{(v^1)^2}{r^1}$ - - (3)

since $M = M^1$

$v = 2 \pi r N$ - - (4)

N being no. of revolutions.

Subs. v in (3)

$\frac{4 N^2 \pi^2 r^2}{r} = \frac{(4 N^1)^2 \pi^2 r^2}{r^1}$ -(5)

$N^2 r = (N^1)^2 r^1$ - - - (6)

$N^1 = \sqrt{\frac{N^2 r}{r^1}}$ - - - (7)

r^1 = radius of new centrifuge

N^1 = no. of revolutions required

†Proceedings 22d An. Con. A. O. A. C., p. 42.

ples; in fact, some of the analysts reporting above got results that are not comparative even for the same analyst. The associate referee (Mr. Hortvet) says that he has never regarded the method otherwise than as quick and approximate. The writer is convinced, from experience, that differences in results are due to differences in reagents and in whirling; it is almost impossible to prepare the reagents exactly alike each time; and it is quite impossible to give each determination the same amount of whirling. Among the writer's first experiences with this method are the following results on three different sirups, in triplicate:

Sample A	B	C	Blank.
2.40	2.75	2.55	.35
2.50	1.80	2.15	.30
2.35	2.45	3.10	.40

Using this method on commercial samples of maple products, the writer has obtained the following results:

Hortvet number.	Complete analysis showed sample to be:
0.1	Adulterated
0.5	"
0.2	"
0.6	"
2.1	Partly maple.
3.4	Pure.
2.0	"
2.0	"
2.3	"
3.0	"
2.0	Adulterated.
0.4	"
0.3	"
3.0	Pure.
0.2	Adulterated.
3.0	Pure.
0.4	Adulterated.
3.5	Pure
5.0	"
3.5	"
0.6	Adulterated.
0.6	"
3.0	Pure.
0.5	Adulterated.
2.3	Pure.
0.7	Adulterated.

CANADIAN METHOD.*

In this method the weight of the lead subacetate precipitate is determined as follows: 5 g. of sirup or sugar are weighed into a large test tube and dissolved in 20 c.c. water. Add 2 c.c. subacetate of lead solution (Sp. gr. 1.26) (Official, A. O. A. C.) mix, let stand two or three hours, filter into a sugar tube, wash four or five times with warm water, dry and weigh. The result is expressed in grams per 100 grams of dry substance. Assuming the average amount of dry substance in sugar to be 90% and in sirup 65%, the weight of lead precipitate from sugars is multiplied by 22.22 and from sirups by 32.5 to obtain weight per 100 grams of dry substance. Genuine products give above two grams lead precipitate per 100 grams dry substance; doubtful samples give between 1.8 and 2.0 grams, while adulterated samples give less than 1.8.

This method gives satisfactory results in the Canadian laboratory where a great many samples of sirup and sugar are analyzed annually. In connection with this "lead precipitate" determinations are also made of ash, and in doubtful cases, malic acid value.

Averages† taken from the Canadian Bulletins show that in pure products there is a relation between "lead precipitate" and "ash," which is an indication in doubtful cases. Pure products give the following:

Lead Precipitate.		Ash.
Range.	Average.	Average.
2.0-2.5%	2.38%	0.65%
2.5-3.0	2.73	0.68
3.0-3.5	3.26	0.77
3.5-4.0	3.60	0.81
4.0-4.5	4.19	0.90
4.5-5.0	4.71	0.97
5.0-5.5	5.25	0.97
5.5-6.0	5 71	1.06

The writer has used this method with good results; discrepancies in results by this method are due principally to the danger of not washing out all sugar, or washing too much and in that way

*Bul. 140, Inland Revenue Dept., Ottawa, Can.

†Compiled by the writer.

dissolve some of the lead precipitate, lead malate being somewhat soluble. The amount of water to be used for washing should be specified. The writer's results by this method are as follows:

Lead precipitate.	Complete analysis showed the sample to be:
0.0	Adulterated.
1.1	"
2.4	"
2.2	"
3.7	"
5.5	Pure.
4.2	"
0.9	Adulterated.
1.7	"
1.6	"
5.8	Pure.
0.9	Adulterated.
4.9	Pure.
0.0	Adulterated.
6.6	Pure.
7.6	"
5.1	"
1.6	Adulterated.
2.2	"
1.6	"
4.5	Pure.
4.5	"
1.9	Adulterated.

It appears from these results that the minimum for pure products should be somewhat higher than 2.0.

WINTON METHOD.*

In this method the amount of lead precipitated by a maple product is determined as $PbSO_4$ and calculated to lead in 100 grams of substance. The process is as follows: Weigh 25 grams into a 100 c.c. flask; add 25 c.c. standard lead subacetate solution, fill to mark, shake, let stand one hour, filter. Take 10 c.c. of the filtrate, dilute to 50 c.c., add moderate excess H_2SO_4, also 100 c.c. of alcohol (95%), let stand over night, filter

*Jour. Am. Chem. Soc., 28, p. 1204.

on Gooch, wash with alcohol, dry, ignite to low redness for three minutes, cool and weigh. Calculate to Pb, and subtract this from the Pb found in a similar manner in 2.5 c.c. of the standard lead subacetate solution, and multiply* the remainder by 100; this result gives the "*lead number.*" The standard lead solution is made by adding four volumes of water to the A.O.A.C. official† lead subacetate solution.

This method gives good comparative results; these results are not absolute, since they are subject to variations due to volume of precipitate produced, which in some cases is quite large; if any error is introduced it appears in the result multiplied forty times; like in all other lead precipitate methods mentioned so far, it is also subject to variation in samples where fermentation has produced CO_2. The method has advantages over those in which the volume of precipitate is measured, both in manipulation and accuracy of results.

The writer obtained the following results:

Winton number.	Complete analysis showed the sample to be:
0.13	Adulterated
0.22	"
0.10	"
0.11	"
0.55	"
1.24	Pure.
1.54	"
1.46	"
1.29	"
1.33	"
0.24	Adulterated.
0.36	"
0.31	"
0.06	"
1.49	Pure.
1.10	"
1.80	"
0.01	Adulterated.
0.03	"

*In Winton's description he omitted stating that remainder should be multiplied by 100.

†Bul. 107, p. 40.

1.91	Pure.
1.65	"
1.29	"
1.23	"
0.28	Adulterated.
0.48	"

HILL AND MOSHER METHOD.

Several years before Jones or Hortvet published their methods, Professor H. M. Hill, of the University of Buffalo, had worked out and was using a method in which he decomposed the lead precipitate with H_2S and determined volumetrically the acid radicals which were combined with the lead;* the acids were all calculated and reported as malic acid. Professor Hill used this method with great success in a great many court cases years before other chemists would undertake to prosecute adulterated maple products.

Dr. Hill has never published this method, although a few other chemists knew it as early as 1904.† As originally used, it is as follows: Take 50 c.c. sirup, dilute with 200 c.c. water, add drop by drop to slight excess, a saturated solution of neutral lead acetate, warm gently to coagulate the precipitate, let settle, filter, wash free from lead acetate; transfer filter and contents to beaker, add water and pass H_2S through; filter, wash, boil out excess H_2S from filtrate, cool, titrate with tenth-normal NaOH, using cochineal indicator. Pure sirups give a colorless or nearly colorless filtrate from the PbS; adulterated samples give brown or black filtrate. Genuine sirups require from 15 to 18 c.c. of tenth-normal NaOH per 50 c.c. of sirup, corresponding to 0.20 to 0.25 g. malic acid per 100 c.c. of sample. All samples known not to be maple required less than 10 c.c. tenth-normal alkali per

*Blythe, in "Foods, their Composition and Analysis," p. 110, says: "It has been proposed to precipitate the sugar with acetate of lead, and thus obtain the lead salts of the organic acids. The lead compounds are decomposed in the usual way, and the acids set free titrated by potash." The Hill and Mosher method is therefore an adaptation of this idea for the determination or organic acids in maple products.

†A reference to this method is found in "Technology Quarterly," 1905, p. 146. Prof. Woodman here reports some results obtained by this method.

100 c.c. sirup. If pure maple sirup be diluted with granulated sugar sirup, the only change in results noted is the lower acid figure.

As will be noted from this description, the color and clearness of the filtrate from the PbS as well as the number of cubic centimeters of tenth-normal alkali required are the indications of the purity of a sample.* In the following table there is given some of the first work by the authors of this method. The "malic acid" is obtained from the titer by multiplying the number of c.c. of tenth-normal alkali by .0067:

Lab. No.	Pb S Filtrate	Malic Acid	Polarization		Remarks
			Direct	Invert	
7876	Nearly colorless	0.210			Pure Sirup, made in Lab.
7934	Brownish	0.243			" " " " "
7976	Nearly colorless	0.209			" " " " "
9004	Colorless	0.247			" " " " "
9085	Colorless	0.267			" " " " "
9108	Colorless	0.203			" " " " "
8728	Black	0.039	+ 64.1		No maple
8729	Brown	0.146			" "
8805	Black	0.023	+ 88.7	− 61.8	Mostly glucose
8806	Black	0.045	− 83.8	− 64.5	" "
8807	Black	0.024	+ 86.2	− 54.1	" "
8808	Black	0.025	− 35.7	0.0	Cane + invert sugar
8809	Black	0.025	+ 39.8	− 14.6	Contains glucose
8811	Brown	0.030	− 36.3	− 14.2	" "
8812	Black	0.035	+ 77.0	− 36.6	" "
8813	Black	0.029	+ 101.0	− 74.5	Mostly glucose
8814	Black	0.000	− 82.6	− 57.3	" "
9131	Light brown	0.122			40 % Cane sugar

*If the first, or lead acetate precipitate, is granular and white, or nearly so, and settles quickly, this is mostly lead malate and indicates a pure sample. Adulterated samples produce a flocculent, bulky precipitate which settles slowly; it consists mostly of coloring matter and resins.

face. 351

SIRUPS

Lab. No.	Lead acetate precipitate	Pb S Filtrate	Time M/10 alk.	Malic Acid	Total Ash	Color of Ash	Water sol. Ash	Insol. Ash	Alk. sol. Ash cc/10 @ 9	Alk. insol. Ash cc/10 @ 9	Remarks
10201	, light	clear	2.7	0.018	0.05 %						Very little maple
10202	+, light brown	clear	20.9	0.140	0.35	green					Pure maple
10203	+, brown	turbid	2.5	0.017	0.11						Adulterated
10204	—, dk. brown	turbid	1.6	0.011	0.05						No maple
10188	—, brown	turbid	2.3	0.015	0.37						Maple and cane
10306	, lt. brown	clear	37.3	0.250	0.31	green					Pure maple
10307	, dk. brown	turbid	0.6	0.004	0.04	trace green					Little maple
10308	+, lt. brown	sl. turbid	12.9	0.086	0.37	green					About 50% maple
10309	trace	turbid	0.3	0.002	0.01						No maple
12220	+, white	clear	35.0	0.175	0.46						Pure maple
12221	+, brown	clear	24.9	0.167	0.47	green	0.30	0.17	0.32	0.38	Cane with little maple
12222	—, dk. brown	turbid	3.7	0.025	0.69	green	0.52	0.17	0.62	0.45	Cane with trace of maple
12223	—, brown	turbid	10.1	0.067	0.65	green	0.56	0.09	0.63	0.32	Cane and maple
12224	+, lt. brown	turbid	12.4	0.083	0.49	green	0.33	0.16	0.33	0.42	Cane and maple
12226	—, v. dk. br.	turbid	11.0	0.074	0.83	green	0.66	0.17	0.74	0.31	Partly maple
12227	—, dk. brown	turbid	6.5	0.043	0.68	green	0.53	0.15	0.61	0.39	Little maple
12129	—, brown	turbid	6.7	0.045	0.19	green	0.11	0.08	0.26	0.40	One-third maple
12130	—, brown	sl. turbid	2.8	0.019	0.62	green	0.32	0.30	0.44	0.45	About one-tenth maple
12131	—, brown	turbid	3.6	0.024	0.81	green	0.75	0.06	0.75	0.20	Little maple
12358	, light	clear	29.8	0.200	0.46	green					Pure maple

Soon after Hill and Mosher began using this method, the writer became connected with Dr. Hill's laboratory and analyzed a great many samples of maple sirup and sugar; the main indication as to purity of the sample was that obtained by this method, which, of course, was supplemented by other analytical data. As will be seen from the following table and discussion, the Hill and Mosher titer was not always a reliable indication; this was due chiefly to the fact that in some cases the filtrate to be titrated with alkali and cochineal was too dark in color for observing the end reaction accurately; another reason was that specific directions were not given or followed as to amount of water to be used in

Plate 17. Maple grove during sugar season.

washing the lead acetate precipitate, the latter being somewhat soluble in cold and more so in hot or warm water; since the filtrations were sometimes made before the solution had cooled and then washed with varying amounts of water, the amount of lead precipitate dissolved and lost in this manner was too great to be ignored. In the writer's method, to be described later, account is taken of the solubility, experiments being recorded to show solubility. The troublesome end reaction in dark filtrates is entirely avoided, the method being gravimetric instead of volumetric. Since completing the work on the gravimetric method, the writer

has discovered a process by which dark filtrates from PbS in the Hill and Mosher method may be titrated and a good end reaction obtained. The color of filtrates from H_2S precipitations is due in many cases to suspended or colloidal sulfids; the writer found that by adding chloroform or carbon tetrachlorid and shaking, these filtrates from the lead precipitate became clear enough for observing the cochineal end reaction.

The somewhat incomplete table opposite page 352 gives the results of some of the early work when the Hill and Mosher method was first used.

The conclusions given under "remarks" were based almost entirely upon the Hill and Mosher titer and malic acid; if a complete analysis, including the more recent tests, were made on some of these samples, the conclusions would probably be modified. The total ash in Nos. 12221, 12222, 12223, 12224, 12226, 12227, 12130 and 12131 is sufficiently high in each case for a pure product, each having also the characteristic green color; some of these appeared to be pure, judging by the Hill and Mosher malic acid. Samples 10202 and 10306, which were called pure, have a very low ash, which may be due to prolonged heating. In a number of samples where the results did not appear concordant, it was customary to repeat the Hill and Mosher titer; frequently these duplicates would agree fairly well; sometimes however there was considerable difference.

	Titer, c.c./10 alka[illegible]
No. 10201 gave	2.7 and 0.6
No. 10202 gave	20.9 and 31.5
No. 12221 gave	7.5 and 24.9
No. 12224 gave	18.4 and 12.4 and 22.6

The only other results on record by this method are those of Woodman,* who says, that while this test is rather tedious and disagreeable, it gives characteristic results; that the color of the PbS filtrate was very striking and served excellently to differentiate the impure samples.

(To be continued.)

*Tech. Quarterly, 18, p. 152.

Section of Mining and Metallurgy.

(Stated meeting held Thursday, October 1st, 1908.)

Opening Address.

Opening Address of Prof. A. E. Outerbridge, Jr.,

President of the Mining and Metallurgical Section.

The speaker gave a resumé of the progress in the Metallurgical Arts during the past two years, and said that the principal advances noted by him within that period have been along the lines of perfecting various new processes that had been previously discovered and announced to the world.

In the working of steel, for example, astonishing results in increased speed of cutting, planing, turning, filing and machine finishing generally of this metal have come from the substitution of so-called "alloy-steels" in place of "carbon-steels'" heretofore used for cutting tools. Formerly a carbon steel tool which would cut off great chips from a rough forging of a shaft, or an anxle, when turned in a lathe, at a speed of thirty to thirty-five feet per minute without having its cutting edge destroyed in a short time was considered a first-class tool, but such puny records are not tolerated at all to-day. The speaker exhibited a cutting tool of tungsten-steel, which was used as a "roughing tool," for cutting or turning off the rough surface of a soft steel shaft $6\frac{1}{2}$ inches in diameter, at the extraordinary rate of 95 feet per minute, the steel chips being $\frac{1}{4}$ of an inch thick ($\frac{1}{4}$ to $\frac{3}{8}$ inch depth of cut, 1/16 inch feed), the cutting continued for nearly an hour without destroying the tool, notwithstanding that it became red hot on the "nose" or lower end, while the steel chips were too hot to touch and assumed a bright blue color from oxidation.

In 1905 the speaker announced before the Matallurgical Section

of this Institute a new discovery in the treatment of cast-iron while in the molten state, after it had been withdrawn from the melting furnace, whereby the strength was increased and at the same time the ordinary brittleness and hardness of cast-iron was largely eliminated. The process consists simply in adding to the molten metal, just before pouring it into the moulds, a very small quantity of an alloy containing fifty per cent. or more of the element called silicon. This alloy is a comparatively new product now being made in the electric furnaces with intense heat and was at first only used for treating molten steel in quite a different way for a totally different purpose. At the time this new announcement was made, three years ago, there was practically no demand for the alloy in the six or seven thousand foundries in this country engaged in making iron castings, but since the publication in the *Journal* of the Franklin Institute in December, 1905, of the results of the speaker's experiments and investigations with "Ferro-Silicon in the Foundry," a rapidly increasing use for the high-grade silicon alloy in iron foundries in this country, and also in Europe, has sprung up, the beneficial effects being found greater than was at first claimed.

The next topic discussed was the recent investigations into the character and composition of the moulds into which molten iron and steel are poured, and samples were shown of the various crude materials, such as moulding sand, carbon dust, etc., from which such moulds are made, together with the finished products (in the form of moulds and cores) that were actually strong enough to be passed from hand to hand and roughly handled without injury. A modern "centrifugal process" for mixing the heterogeneous compounds used in making moulds was described and pictures were thrown upon the screen showing the machines and the products.

The reduction in cost of making moulds and cores by moulding machines, in place of hand moulding, was stated to be more than fifty per cent. in the majority of cases, where many castings are made from one pattern.

The speaker called attention to the remarkable progress recently made in reducing low-grade metalliferous ores and recovering the metals at a profit, which were formerly of no value, and instanced the recovery by such methods of the precious metals, gold and silver, and base metals, lead, zinc, etc., from

"tailings" that were cast aside at the mines and formed huge dumps of refuse.

According to conservative estimates made in 1905, zinc tailings at the Broken Hill field, in New South Wales, alone amounted to 5,700,000 tons, valued at $57,000,000.*

With a view of obtaining a process capable of dealing with this waste material profitably, the various companies in that region offered large monetary rewards for a successful method. Metallurgists all over the world began experimenting, and several radically different, but highly ingenious and practical schemes were devised, some of which are daily at work rapidly recovering this vast quantity of metal now lying fallow, and large as these "dumps" are, they are mere ant hills compared to the mountains of waste tailings at mines in various parts of the world waiting to be treated for the profitable recovery of the metals they contain.

In conclusion the speaker said, that the prospects of increased activity in all metallurgical operations, after a twelve month's breathing spell, are quite encouraging for the coming year, and he congratulated his hearers upon the prospects before them of increased activity in their various occupations. He said, within a few days, indeed, signs of a change in the prevailing "trade winds" have been observed in Pittsburgh and other industrial centers, showing quite a freshening breeze that will, it is hoped, not prove a fitful gust, but will continue steadily increasing in force so that ere many weeks shall have elapsed, we may look back upon the present period of depression as a thing of the past, from which valuable lessons may be learned.

SULPHUR AND PYRITE INDUSTRY IN 1906.

The sulphur industry of the United States during the last few years has been characterized by steady growth in consumption, increase in production, and decrease in quantity and value of imports as a result of the development of domestic resources.

Statistics collected by Dr. David T. Day, of the United States Geological Survey, and published in an advance chapter of "Mineral Resources of the United States, Calendar Year 1906," show that the domestic production increased from 181,677 long tons, valued at $3,706,560, in 1905, to 294,153 long tons, valued at $5,096,678, in 1906. Exports amounted to 22,237 long tons, valued at $460,435.

---

*See Engineering Magazine, September, 1908.

The great production of sulphur in Louisiana continued in 1906, and the success of the Frasch sulphur process, by which the mineral is melted by streams of superheated water pumped into the Louisiana wells, has been fully demonstrated. Local demands for sulphur for sheep dip and for use in destroying vegetable parasites have been very well met by developments in Utah, Wyoming, and Colorado.

The dominating factor in the world's supply of sulphur has been the production of the material in Sicily, which, in 1906, showed a large decrease, chiefly due to the loss of the American trade through the development of the Louisiana deposits. The exports from Sicily to the United States have decreased steadily for the last four years—from 155,996 long tons in 1903 to 41,283 tons in 1906.

The pyrite production of the United States increased from 253,000 long tons in 1905 to 261,422 long tons in 1906, but the price declined from an average of $3.71 per ton in 1905 to $3.56 in 1906, causing the total value to decrease from $938,492 in 1905 to $931,305 in 1906.

Pyrite burning entered significantly into the sulphuric-acid business in 1882, when the product was 12,000 tons. In 1885 the product had increased fourfold; five years later it had nearly doubled again, and increase has since been rapid. The growth has been due not only to the cheapness of this source of sulphur but to the use of the cinder in the blast furnace. The dominant position in the pyrite supply is occupied by Virginia, and California and New York follows.

More careful attention to waste products in copper, lead, and precious-metal smelting will lead in the near future to a production of sulphuric acid in such quantities as to affect commercial conditions very appreciably, and these sources of the acid must be taken into account.

PRECIOUS METALS MINED IN 1906 IN SOUTHERN APPALACHIAN STATES.

The southern Appalachian States, including Alabama, Georgia, North Carolina, South Carolina, Tennessee and Virginia, yielded $295,335 in gold in 1906, a decrease of $158,841 from the figures of 1905. The output of the first four States was notably less, and only Tennessee and Virginia reported increases.

North Carolina still shows the largest output—$82,131—and is closely followed by South Carolina, with $78,959. The greatest decrease—$65,860—is shown by Georgia, whose production amounted to only $31,050.

As usual, silicious ores yielded the largest amount, principally from the Hillabee mine in Alabama, the Haile mine in South Carolina, and the Iola mine in North Carolina. The placer gold aggregated $30,000 in round figures.

Of silver 87,765 ounces were produced, a decrease of 29,744 ounces from 1905, the greatest loss being apparent in Tennessee copper ores. The only States having an important output of silver were North Carolina, with 30,769 ounces, and Tennessee with 55,931 ounces. Almost the whole silver output is derived from copper ores.

The gold and silver production of the United States are described by Waldemar Lindgren, geologist, of the United States Geological Survey, in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which will be ready for distribution by the Survey some time in December.

(Stated meeting held Thursday, October 1st, 1908.)

Economy in Purchasing Supplies.

By Robert Job,

Member of the Institute.

The purchase of the supplies of a large corporation under present-day conditions has become a most important factor in the successful conduct of the business, and at the opening of the year's work of the Institute, it may be of general interest to consider some of the conditions and precautions which are observed to obtain the greatest efficiency of material at the least possible cost.

At one time high cost was to a certain extent an indication of high quality, but one soon learns without extended business training, that quality sometimes bears an inverse relation to the price, and in any event that the latter can seldom be depended upon as an exact measure of utility.

These facts have lead to an accurate study of the properties necessary to secure favorable service results under different surrounding conditions, and definite standards in many cases have been worked out, detailing in as simple form as possible the requirements necessary to efficient results. These specifications, as is well known, are submitted to the dealers for bids; the orders are placed with the lowest bidder, and a sample of the shipment is taken upon receipt and tested in order to be certain that the material is fully in accordance with the requirements. When below the specified limits, the shipment is rejected and the freight both ways is paid by the shipper.

It is a matter of general observation, that the highest quality of a given material is not by any means necessarily the most desirable in service, and consequently there is often direct loss without corresponding gain when one merely purchases upon this basis with-

out regard to the properties necessary to ensure long life. An example will point our meaning: Let us suppose that freight car paint is desired of good appearance and of great durability. If we select sesquioxide of iron for the coloring matter, as is usually done, it is well known that thirty per cent. or so of oxide or iron will give ample covering or hiding power, and that a larger proportion does not increase the efficiency of the paint as to either color or durability, while the use of relatively cheap inert fillers when of proper physical condition may even cause decidedly increased life. Hence, insistence upon use of pigment consisting solely of sesquioxide of iron, or other coloring matter, is of no practical advantage for such work and would raise the cost of the paint without increasing its efficiency.

If the paint were desired for tinting purposes the case would be different and the greatest possible strength or coloring power would then be specified and would be fully utilized.

From the discussion above it will be clear that specifications to be efficient must be based upon a study of the properties of the material under the conditions which exist in service, and not upon mere trade quality. The prime essential is that a quality be specified which will give the most effective results, and it is equally important that definite methods of test shall be stated, or shall exist, which will enable the purchaser to determine whether the desired properties are present. Specifications which are not systematically enforced are far worse than useless since they may seem to give a measure of security which may be wholly lacking in fact after the first shipment or two.

Having fixed upon the most suitable quality, the price is determined by competition. In some cases the price will be unchanged by the specifications, but generally a higher quality of material will be obtained at a given expenditure. Frequently, however, an astonishing difference in cost occurs as a result of the specifications, and we have in mind an instance in which a certain compound was obtained by this method for one-tenth the former cost. Sometimes a difference of fifty per cent. is obtained, frequently with increased efficiency in service in addition to the reduction in cost.

Some articles largely used are manufactured and sold under trade names, and often the price is out of all proportion to the true value. Many of these materials, such as disinfectants, car

cleaners, boiler compounds, polishes, etc., can be easily made up, often for one-quarter of the regular selling price.

Other materials, as for instance, oils, special alloys, etc., can be obtained under specifications at a market value much below the prices usually charged by the dealers, with generally better service owing to the greater uniformity of the shipments.

One source of great economy in maintenance lies in the systematic study of waste materials. In railroad operation, and in fact in almost any large enterprize many chances for such work exist. An instance of this type in the writer's railroad experience will illustrate the point. A large number of track batteries were in use in connection with the track signals, and as the renewals for these were a large item of expense, a careful study was begun to devise, if possible, some plan whereby the exhausted material might be renewed. The investigation was carried on step by step, and a method was finally worked out upon a commercial scale by which the worn out element was brought back to its original condition at a trifling expense. The other materials used in the renewals were put upon a specification basis, and as a result of the investigation, the cost of the renewals was reduced to less than one-quarter of the former price, with higher efficiency than was originally present.

Sometimes heavy loss results from the purchase of material which is of high grading for the simple reason that the properties present may be radically different from those essential to successful service. At one time we recall that cast-iron wheel centers, cylinders, and other castings were breaking rapidly in service after a comparatively short life, and a careful investigation was made to determine the causes, and put a stop to the loss. A special high silicon low sulphur No. 1 foundry iron was in use, recommended by the furnace people particularly for such work. On investigation it was found that the proportion of phosphorous was much beyond the point desirable in castings exposed to sudden impact, and the high silicon was also a source of weakness for such service. As a remedy, specifications were drawn up placing the limits in the pig iron and in the coke at the points generally recognized as necessary to produce in the castings the desired properties. Also a thorough study of foundry practice was made and methods were introduced for the deoxidation of the iron in order to secure tough, dense metal free from hardness or spongi-

ness. Every carload of the pig iron and of the coke was tested before used, and if not in accordance with the specifications it was rejected.

The new grade of iron was obtained at a lower price than the former quality, and practically a complete stop was put to the difficulties which had occurred, and the life of the castings was very much increased. Thus the higher grade did not have the properties essential to good service, and a large economy was effected by selection of material at lower initial cost but having the desired character.

Still another fruitful source of economy lies in the careful study of failures in service in order to determine the precise cause of the failures and devise methods for avoiding repetitions. The study of defective iron castings has already been referred to and an equally profitable field lies in the investigation of brass castings and babbitt metals. Hot boxes are often a heavy item of expense and repay careful investigation. This difficulty may be due directly to incorrect foundry practice or composition and may be largely remedied by properly enforced specifications. In some cases unsatisfactory service will be due to failure to get a metal adapted to the requirements, and we have in mind an instance in which the cost of a bearing metal was reduced 75 per cent. owing to the fact that an antimonial lead mixture was better adapted to the conditions than the harder and more expensive brass had been. In this case the unsatisfactory results were stopped and decided economy resulted both by bettering the service as well as by the lowering of the cost of the metal.

The thorough study of failures of steel rails opens another line of work by which great economy may be gained in the purchase of material. Steel rails are a large item of expense in the operation of a railroad, and whatever will tend to decrease the failures of the rails and lengthen the life is certain to bring gratifying results not only in economy of operation but also through increased safety. Many types of failures of rails are caused directly by improper practice at the mill, as for instance in failure to crop ingots to sound metal, and as a result fracture or slivering occurs after relatively short service. At times the steel is too soft and the metal cuts out under heavy traffic. These evils can be very largely prevented by carefully arranged specifications and by placing a sufficient force of thoroughly trained men at the mill to be

certain that the provisions are fully carried out. Precautions such as these are comparatively inexpensive and they pay for themselves over and over again in the increased efficiency of the product.

In certain cases the process by which material is made has a decided influence upon the efficiency. A striking example is found in the manufacture of steel. As is well known, many articles of steel are made up by the bessemer process, and the strength and serviceability at times are decidedly decreased by the proportion of phosphorus with its attending brittleness. If made by the basic open-hearth process both phosphorus and sulphur can be largely eliminated and the tenacity of the steel under impact so greatly increased that a much higher proportion of carbon is safe, producing greater hardness and a larger capacity for wear. These facts have an important bearing in the case of steel rails, for soft-brittle steel commonly used in the past, with carbon contents, say of about 0.50 per cent. and phosphurus of about 0.10 per cent, can be replaced by steel in which the phosphorus is reduced to about 0.02 per cent. or less, and we have known of instances in which the two types of rails laid side by side in track showed only one-third the amount of wear in the latter as in the former quality, with the factor of safety and freedom from fracture greatly increased. The cost of manufacture by either process is practically the same. It should, however, be borne in mind that the mere fact that the steel has been made by the basic open-hearth process is no assurance that the quality will be satisfactory, and in consequence the precautions alluded to above are essential to good service.

Our theme might be extended almost indefinitely with illustration after illustration of economy effected by the systematic working of the general plan which has been outlined. The typical examples which have been cited will, however, give a clear indication of the possibilities of the system, and may, we hope, be of some assistance in suggesting means by which costs of operation may be materially reduced.

TREES AS CROPS.

"It is as sure that forest land can be made to grow successive crops of trees under proper methods as that plow land can be made to grow successive crops of wheat," says the Secretary of Agriculture in the part of his annual report wherein he speaks of the National Forests.

This country, which once could boast of forest resources richer than any other nation in the world, has been cutting three times as much timber for a number of years as there is grown, and the consideration of timber as a crop to be carefully harvested has come at a time when many of the virgin forests are already depleted. Continuing, Secretary Wilson says in part:

"Just as American farming has had to develop and is still developing methods adapted to the conditions of each region to make the best use of the agricultural lands, so must the forester learn by scientific study and practical trial to make the best use of our timberland. And the best use means, of course, not merely its best use for the growing of trees. but its best use with reference to all interests directly or indirectly affected by it.

"As time passes, it will doubtless appear that the principles which centuries of experience in older countries have placed at our command can be applied with increasing good results as we grow more familiar with our own special conditions. The issue is sharply between caring for our forests by applying a system of known efficiency, or suffering certain loss not only of the forests, but of usable water and soil as well, through the operation of causes as certain to act as are the rivers to run to the sea."

The Forest Service now has administration over more than 164,000,000 acres of land. This is slightly more than one-fifth of the country's total forested area; the remainder is in the hands of private owners. Nearly all the timberland in the unappropriated public domain is now in the National Forests. This means that it is being protected against fire, theft, and wasteful exploitation, that its power to grow wood and store water is being safeguarded for all time, and that nevertheless, its present supply of useful material is open to immediate use whenever it is wanted. The report says:

"The timber in the National Forests, which is the legacy of the growth of centuries, is now in the truest sense public property, administered for the benefit of the people—primarily for the benefit of the people of the West, since they are nearest at hand, but on the whole, for the benefit of every part of the country, since the welfare of every section is interwoven with that of all others. The communities and settlers adjacent to the forests are safe from any fear of monopoly of one of the chief necessities of civilized man."

The Secretary tells interestingly of how the government manages its timberlands as a trustee. It gives timber away through free-use permits in small quantities to the actual homemaker, who comes to develop the country, and in larger quantities to communities for public purposes. Its system of management is vastly different from that of a landlord. When large quantities of timber are harvested from the National Forests, sales are made to the highest bidder, but under such restrictions as look to the maintenance of a lasting supply answering to the needs of the locality, to be had without favoritism and without extortionate demands based upon the necessity of the consumer.

Mechanical and Engineering Section.

(Stated meeting held Thursday, October 15, 1908.)

The Water Supply of Philadelphia, With Special Reference to the Filtration Works Now Under Construction.

By John C. Trautwine, Jr.,

Member of the Institute.

With equal propriety, this paper might have been entitled "An Experiment in Socialism." Socialism proposes to take private property and private industries, with or without the consent of the owners (by right of eminent domain, if necessary), and private services, and to administer this property and these services for the benefit of the public. It thus proposes to crush out private initiative, to create an army of public mercenaries, and to interfere, in a thousand ways, with our personal liberties; and all this in order that it may "abolish poverty," a suggestion which arouses our ire or our mirth, according to our temperament.

In our public water supply, all these threats have been carried into execution. Private property and services have been taken for the public benefit; the private enterprise of the water peddler has been crushed out; the Water Bureau has a thousand or two of employees, paid out of the city treasury, and it is the duty of some of these employees to enter our dwellings and places of business, with or without our consent, to pry into the character of fixtures installed at our own expense, and, if these do not meet their approval, to compel us to replace them with others. Health officers are even presuming to dictate to individuals, in what locations they may not use their old-fashioned pumps, and, to manufacturers, what portions of their offal they may not throw into the streams which flow past their doors.

And, worst of all, poverty has been abolished, in so far as a water supply can reach. The man of to-day, who rents a modern house at $12 per month, is infinitely rich, as to water supply, compared with the merchant princes of Philadelphia in 1800. If socialists are permitted to proceed, as they have done since the dawn of civilization, and notably within the last century, the race of paupers will one day be extinct, and our comfortable bourgeois citizens will be left without objects upon which to exercise their benevolence.

SOURCES OF SUPPLY.

The public water supply of Philadelphia has always been taken, it is still taken, and it bids fair always to be taken, from either the Schuylkill River alone, or from the Schuylkill and Delaware Rivers.

The Delaware water shed, above Philadelphia, has an area of some 8000 square miles, and is about 180 miles long, from north to south, and from 20 to 70 miles wide, from east to west. The river rises in the southeastern portion of the State of New York; and, for the greater part of its course, forms the boundary between Pennsylvania and New Jersey. Tide reaches to Trenton, some thirty miles above Philadelphia.

The Schuylkill rises in the anthracite coal regions, near Pottsville, some ninety miles above Philadelphia, by its own windings; and, before reaching Philadelphia, crosses a limestone belt, in the vicinity of Reading, and the broad belt of "new red shale," between Reading and Norristown. Its course lies mostly in rich agricultural country, and passes the large and prosperous manufacturing towns of Pottsville, Reading, Pottstown, Royer's Ford and Spring City, Phoenixville, Norristown and Manayunk, the last named within the Philadelphia city limits. Fairmount dam is now the upper limit of tidal flow; but, before the construction of the dam, the tide backed up to Falls of Schuylkill, where a rapids (afterward drowned out by the building of the dam) gave the place its name.

The anthracite coal mines are indeed socialistically operated, in that the labors of many men are cöoperatively employed for

the supply of coal to the public; but, thus far, the control of these mines has been suffered to remain in the hands of divinely appointed and profit-seeking guardians,* who rule over the divinely-appointed miners, and who conduct the business primarily with a view to profit, and, secondarily, with a view of keeping within the law without unreasonably scaling down said profits. The consequence is that enormous quantities of acid mine water and of fine coal dust are washed into the streams which feed the Schuylkill.

So far as the mine water alone is concerned, the individualistic activities of the guardians result rather beneficially to the Philadelphia water supply; for, in flowing over the limestone belt, near Reading, and receiving the calcareous waters of the Tulpehocken and other streams traversing that belt, the river water becomes impregnated with lime, which doubtless would make the water extremely "hard," were it not that, in great part, this lime is neutralized by the sulphuric acid, which combines with it, forming lime sulphate, which, in turn, is precipitated to the bed of the stream, so that the water, when it reaches the city, is not too hard for domestic and boiler use, although still greatly inferior, in the matter of softness, to the Delaware water.

Above the limestone belt, the water, still carrying much free acid, is of a blackish color, when seen in mass, and foamless when agitated, as in flowing through the lock-gates of the Schuylkill Navigation. But, in its passage over the limestone belt near Reading, and owing, no doubt, to the action between the acid and the lime, the water assumes a remarkable and beautiful blue color (which persists for some little distance below Reading), and develops much white foam when agitated.

As to the coal dust, however, the individualistic activities of the guardians are less distinctly beneficial to the Philadelphia water supply. We are only now awakening to the necessity of socialistic forest-protection; and, while we slumbered, individual enterprise (which is at the basis of all our prosperity) destroyed the forests; so that, now, the rain, falling upon the ground, instead of being retained and paid out gradually, rushes at once into the streams, causing disastrous floods. These bring to us, first, the

*A prominent official of one of the great coal-mining combinations recently referred to those of his class as "divinely appointed guardians" of the common wealth in coal lands.

red-shale mud* from the lower reaches of the river, and, a day or two later, the coal dust, accumulated in the upper navigation dams; so that, frequently, a glass of water, drawn from the city faucet, looks like a glass of ink.

The socialist city has taken the matter into the socialist courts, praying for injunctions against the individualist guardians; and seeking to restrain them from polluting the streams by coal dust; and, as these suits were brought many years ago, it is not impossible that some little good may have resulted.

It is only very recently, too, that socialism has presumed to restrain individual liberty in the matter of throwing chemical refuse, and house and farm sewage, into streams furnishing water supply; and, as a consequence, the Philadelphia water, prior to the installation of filtration plants, was unfit for domestic consumption, and the typhoid rate was entirely too high.

Each of the two rivers has its own peculiarities in the matter of pollution. In the Schuylkill, a relatively small stream, flowing through a densely populated region, with many large manufacturing establishments, the water reaches the city limits highly polluted; but it is in great measure protected, by Fairmount Park, by intercepting sewers, and by Fairmount dam, from the city's own sewage. From those portions of the city above the dam, which drain into the Schuylkill, the sewage is carried, by intercepting sewers, into the river below the dam; and one of the principal arguments for the establishment of Fairmount Park was the protection which it would afford to the water supply, by preventing the discharge of manufacturing sewage into the stream by individual enterprise.

In the Delaware, on the other hand, a much larger stream, flowing through a district much less densely settled, the water, although passing through vicissitudes of much the same kind as the Schuylkill, reaches the city in better condition, as regards both softness and purity; but, on the other hand, it has no protection, by park or by dam, from the city's own sewage, or so much of it as falls into the Delaware,—for this is carried up-stream by every flood tide.

---

*Those in charge of the filtration plants tell us that the particles of the red-shale mud, brought down by the river, are not only very much finer than the finest coal dust, and therefore much more difficult to manage on the filters, but also finer even than the bacteria themselves.

The Lehigh, an affluent of the Delaware, rises, like the Schuylkill, in the anthracite coal regions, and it and the Delaware traverse the limestone and red-shale beds traversed by the Schuylkill.

Prior to the recent changes, about 90 per cent. of the entire supply was taken from the smaller stream, the Schuylkill; very probably because that happened to be the stream first drawn upon.

On the Schuylkill, the Fairmount, Spring Garden, Belmont and Queen Lane stations draw from the Fairmount pool, formed by the City's dam at Fairmount; and the Roxborough station draws from the Flat Rock pool, formed by the Schuylkill Navigation Company's dam at Flat Rock. The Schuylkill supply is thus dependent upon the integrity of these two dams, except that the Roxborough works are provided with special pumps for supplying the main pumps with water from the river at low stage, in case of failure of the Flat Rock dam, several such failures having rendered its integrity questionable.

On the Schuylkill, the City finds itself in conflict with the Navigation Company, which claims the right to prevent the City from drawing down the levels of the pools below a certain minimum, considered by it as necessary for its purposes.

On the Schuylkill, also, the City is, to some extent, at the mercy of the Navigation Company, by reason of the Company's control of its numerous dams, upon the river and its tributaries, above Fairmount. It is only fair to the Company to remark that its justice has been tempered with mercy, that it has frequently come to the relief of the City by letting down some of its stored water, and that it has even offered to bestow its valuable privileges upon the City—for a consideration. Questioned, by a Council's committee, as to the advisability of accepting this offer, I replied that the offer might be worth considering, if disencumbered from the consideration, but not otherwise, inasmuch as the minimum flow of the river was ample for all the City's needs and luxuries—barring only the luxury of waste.

METHOD OF SUPPLY.

Necessarily the supply has always been by pumpage from the rivers, these of course lying lower than the city itself.

At Fairmount, the oldest *existing* pumping station, the pump-

age is done by water power, derived from the river itself by means of the Fairmount dam and the seven turbines. The quantity required, to force one gallon into the Fairmount and Corinthian reservoirs, has been differently estimated at from fifteen to thirty gallons, the quantity, required for power, depending, of course, upon the relative heights of the water up-stream and down-stream, which, in turn, depend chiefly upon the stage of the tide, and, to a less extent, upon the up-stream level.

Owing to the claims of the Schuylkill Navigation Company, the Fairmount works (which are of relatively small capacity) have been increasingly idle, especially during the low water of summer, and it is now proposed that they shall be abandoned as a working factor in the supply; but it is much to be hoped that they will be retained as an object of picturesque and historic interest. Few if any large cities in the world have, so near their centers, so beautiful a spot as the Fairmount hill and water-works. During the Revolution, the hill was occupied by a British redoubt, one of a series of such structures, which extended from the Delaware, near what is now Fairmount Avenue, to the Schuylkill at Fairmount, north of the then limits of the city. The series was completed by a redoubt at 22d and Chestnut Streets, the site of which was afterwards occupied by one of the two pumping stations of the city's first water works, built by Benjamin H. Latrobe and Nicholas I. Roosevelt (brother to the President's grandfather) in 1799-1801.

With the exception of Fairmount, the pumpage is all done by steam power.

Normally, the pumpage has always been to elevated reservoirs, from which the water flowed, by gravity, into the distribution. Even the first works had one and sometimes two wooden tanks in the dome of the tiny station at Center Square. Later, beginning with Fairmount, earthen reservoirs were constructed on more or less elevated sites. The largest of the reservoirs is that at East Park, with three basins, then that at Queen Lane and that at Roxborough, each with two basins. These are the three large reservoirs. The others are much smaller and are now of but little consequence.

Owing, however, to a cause which will be mentioned later, it has often been found impossible, by means of the pumps, to keep up the supplies in the reservoirs against the excessive demand;

so that, in order to avoid the complete emptying of the reservoirs, it has been necessary to resort to direct pumpage, under which the vile fluid of the Schuylkill was forced direct into the distribution, with not even the trifling benefit of sedimentation in a reservoir. Prior to my administration, this was the normal condition with regard to the Spring Garden works, which supplied the major part of the city and pumped more water than all the other stations combined; but, just prior to my term, the Queen Lane pumping station and reservior had been constructed; and these enabled us to reduce materially this serious nuisance.

Besides the stations which drew directly from the rivers, there were several "high-service" stations, located in elevated positions and supplying limited and generally sparsely settled areas, lying at elevations too high to be supplied from the reserviors. Of these, the principal are those at Belmont, supplying Bala, etc.; at Lower Roxboro, supplying Chestnut Hill; and at Wentz Farm, for the supply of Bustleton and Fox Chase.

The Spring Garden pumping station, already mentioned as the largest, is so called from the fact that its nucleus (located in a building of Egyptian design and still standing) was built by the then outlying district of Spring Garden. The station now comprises an upper and a lower house, the former containing about as remarkable a collection of curiosities, in pumping engine design, as I remember to have seen anywhere, outside of Cincinnati, O. From it issues, on the east, a most complicated net-work of large mains, which, of necessity, pass under the numerous tracks of the main line of the Philadelphia & Reading Railway, which runs close by the station. Breakages in these pipes have caused very serious damage to railway and to station, washing quantities of gravel out from under the tracks and carrying it down into the pump wells of the engines.

Adjoining the Spring Garden station still stand the wooden sheds in which was located the city's first experimental filtration plant.

A table below gives data respecting the several pumping stations and reservoirs as they existed in 1898, and as they will be left by the changes now in progress.

A visitor to our water works to-day naturally wishes first to see at least one of the four filtration plants now completed, or nearly so, as these constitute the novel feature; but, prior to their

construction, he was shown the pumps and the reservoirs, these being, in fact, about all that could be shown; and he was apt to come away with the impression that he had seen the water works, whereas really by far the greater portion of the works was under ground and therefore out of sight. An estimate, made some ten years ago, of the cost of the then existing works, distributed the cost approximately as follows:

Pumping stations	$4,000,000
Reservoirs	6,000,000
Distribution	25,000,000
Total	$35,000,000

CONDITIONS IN 1898.

In order properly to understand the recent extensions, consisting of and in connection with the filtration works, we must first take a glance at the conditions existing immediately before those works were begun.

USE AND WASTE.

Until recently the city's only means of determining the quantities of water handled by the pumps was "plunger displacement." A revolution-counter recorded the number of strokes of each pump; and, knowing the dimensions of the plungers and the lengths of stroke, it was easy to determine the quantity which ought to be discharged at each stroke, and what each pump ought to be lifting. As a matter of fact, owing to defective valves, etc., the quantity actually lifted nearly always falls short of the theoretical quantity, determined in this way; and a deduction is made, from the theoretical quantity, to cover this deficiency. In view of the dilapidated condition of many of the pumps, however, it is altogether probable that the deductions so made were insufficient, and the pumpage therefore exaggerated; possibly by as much as 10 or 15 per cent. Making deductions for this, Fig. 1 may be taken as a fair indication of the growth of the city's water consumption, between the years 1860 and 1897. The upper diagram represents the *total* pumpage, in gallons per day, and the lower di-

agram represents the number of gallons pumped *per capita* per day. It will be noticed that, in the thirty-seven years mentioned, the daily total pumpage (estimated as above explained) increased from 20 to 257 million gallons, an increase of nearly 1200 per cent., and the per capita from 36 to 215 gallons, an increase of nearly 500 per cent.

Market Street is 100 feet wide between house lines; and 250,000,000 gallons would fill Market Street, to a depth of 100 feet,

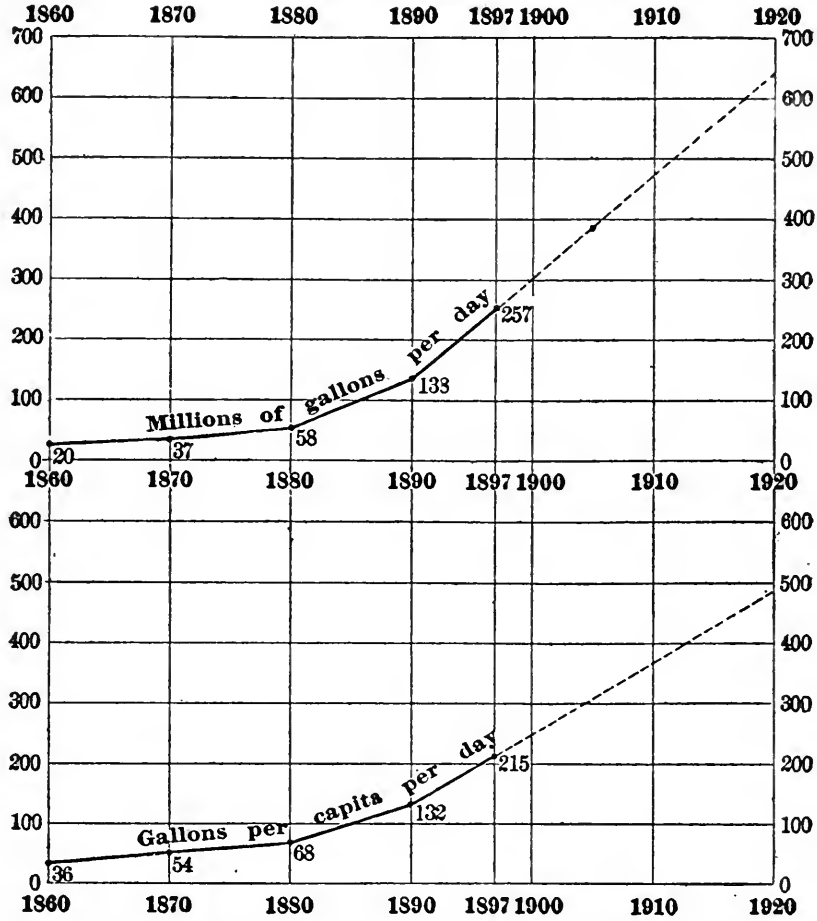


Fig. 1. Daily consumption of water, total and per capita, in Philadelphia, as deduced from plunger displacement.

from the Delaware to 7th Street. The present daily consumption of about 320,000,000 gallons would extend from the Delaware to about 9th Street.

Inasmuch as fifty gallons per capita per day has repeatedly been shown to be a very ample supply, it might be supposed that our citizens, of that time, were deluged with water and complaining of the difficulty of getting rid of it, and that our pumps, if we had

chosen, might have been left standing idle more than half the time.

I quote from my last annual report, that for 1898:

"Our boilers and engines are strained to the utmost night and day, and in some cases disabled; there is no opportunity for thorough repairs; we dare not stop pumping during seasons of muddy water; in spite of all manner of pitiful expedients we are compelled to cut off our reservoirs from the distribution in order to keep them from being entirely emptied; and from all sides come loud and well-grounded complaints from citizens who pay for a water supply but do not get it."

The reason for this is indicated in Figs. 2 and 3, based upon actual and oft-repeated observations of the consumption of water in dwellings. Such an investigation of two intermediate streets, with 142 modern seven-room two-story dwellings, showed

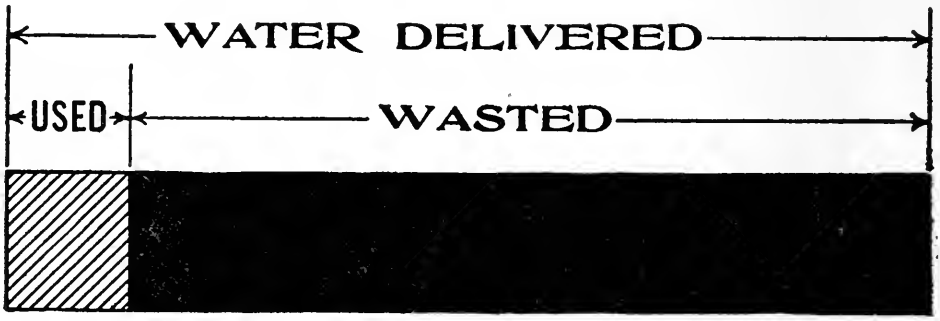


Fig. 2. Use and waste of water in Philadelphia

that, of the water furnished to those dwellings, less than 14 per cent. was used, and more than 86 per cent. was wasted, a state of affairs indicated in Fig. 2.

As nearly as could be judged from the then existing legislation respecting water meters, the Bureau of Water was forbidden to place water meters upon dwellings for the purpose of determining the amounts to be charged for water; but we could not find that we were forbidden to use these devices experimentally; so, after obtaining the consent of the occupants, we placed meters upon twenty dwellings, of different classes. As the use of these meters was purely experimental and did not affect the amounts of the water bills, the consumers were under no inducement to observe more than their usual care in their use of water. The result is shown in Fig. 3, viz., that, of the twenty dwellings, sixteen consumed from 9 to 60 gallons per capita per day, averaging 33

gallons, while the remaining four consumed 142 to 181 gallons per capita per day, averaging 149 gallons.

Figs. 4 and 5 illustrate, respectively, (1) existing conditions as deduced from the foregoing results, and (2) those which might be expected to follow from the general use of water meters.

As indicated in Fig. 4, one person in every five is throwing away, unused, far more water than the other four consume, depriving those four of their proper supply and compelling them to pay for the privilege of maintaining his useless waste.

The water meter compels the one man in five to stop his wasting, saves the quantities wasted, and distributes them among the

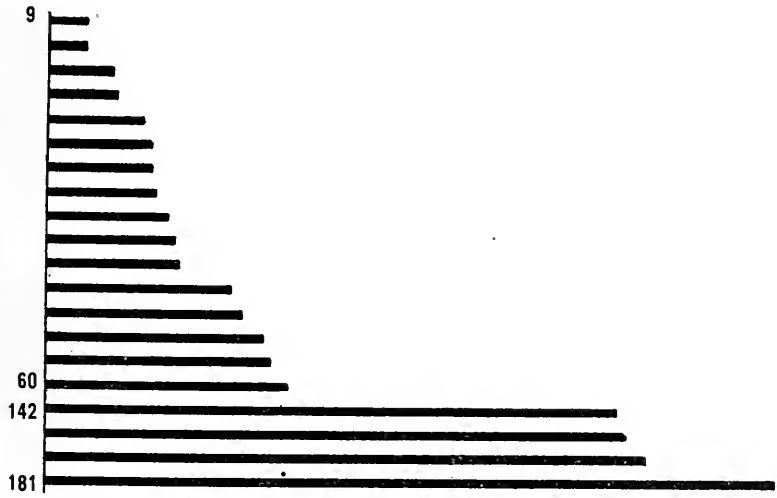


Fig. 3. Consumption of water in twenty Philadelphia dwellings, in gallons per capita per day.

other four, with the result indicated in Fig. 5, viz.: "reduction of bills and increased pressure encourage the liberal use of water." This has been the experience, I believe, wherever the meter has been used. In all such cases, doubtless, the one man in five expostulates, upon the presentation of his first meter bill, and considers the meter an unmitigated nuisance and fraud; but the other four, when they grasp the situation, never fail to sustain the meter. The Mayor of Atlanta, Ga., wrote: "It was a fight, and a sharp one, at first, when we put in the meters and filters. Such, however, has been the effect of experience and education, with demonstration of success, that now I make bold to say it would not be merely a fight, but a revolution, if we attempted to abolish meters and filters."

But, in our community, as in most others where the meter is unknown, the utterly mistaken impression has got abroad that the meter is intended to restrict the *use* of water, whereas, as we have

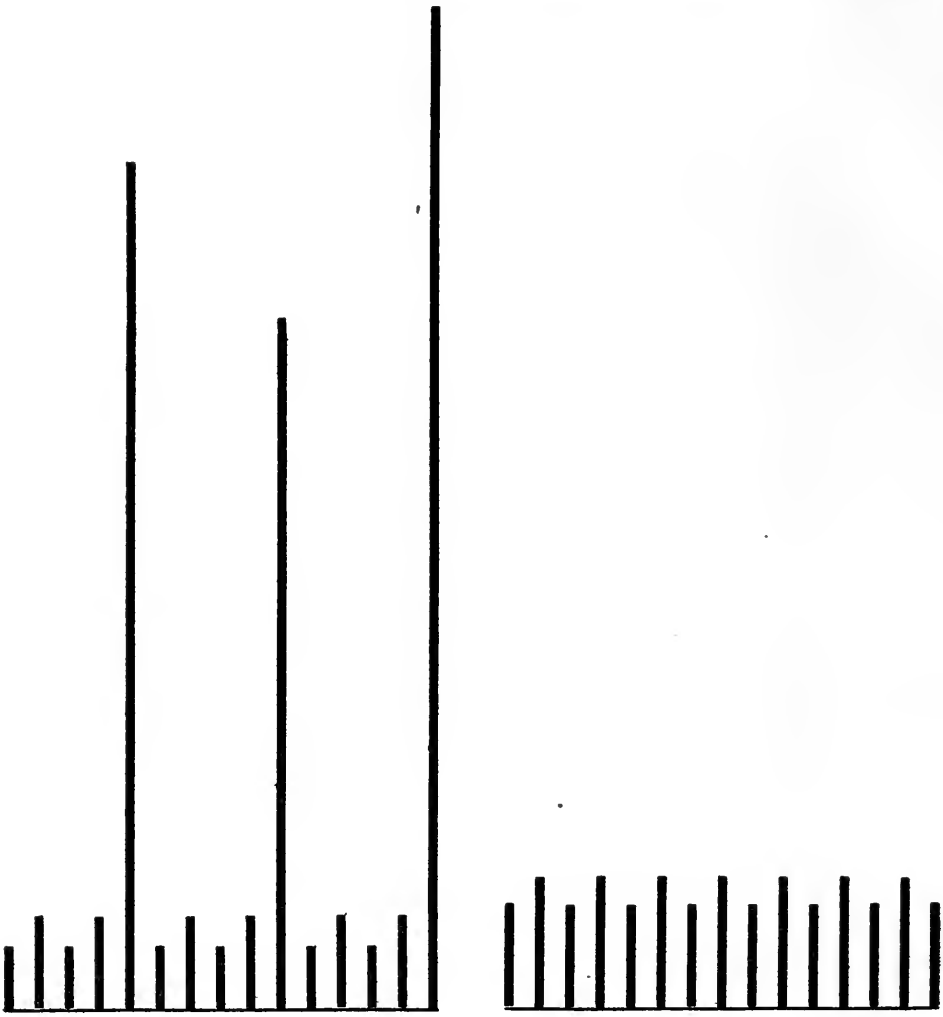


Fig. 4.

PRESENT CONDITIONS.

More than half the water pumped is wasted by less than one fifth of the people.

Fig. 5.

WITH METERS.

Reduction of bills and increased pressure encourage liberal use of water.

The three tall lines, in Fig. 4, represent, by scale, the water consumptions of the few persons, who, by wasting more than we use, deprive us of the full supply we pay for.

In both figures, the short lines represent the water consumptions of the non-wasters, who are in a majority of at least four to one, but who allow the minority to rob them.

In Fig. 5, these short lines are longer than in Fig. 4, because the water, at present wasted by the few, has been saved, by the meter, and given to the many.

seen, its function is, on the contrary, to *increase* that use by cutting off mere waste and by thus rendering the supply, for use, more abundant.

One irate gentleman asked: "How can we waste what we do not get?" The real question was: "How could he get what the other man was wasting?"

Companies, seeking to capture the Philadelphia water supply, naturally harped upon our inability to meet the demand, and their engineers were not enthusiastic for the meter. With these exceptions, I can recall but one waterworks engineer who opposes the use of the water meter. So far as I know, he has the opposition field all to himself.

Placed between the devil and the deep sea, between our inability to keep a sieve full, and the demand of the people that it be kept full and overflowing, and knowing that the water meter would quickly bring us from dark night into day-light, I naturally advocated its use. I knew that, with the meter, the capacity of our works would be practically doubled, and there would be plenty of water for all; that the cost of filtration, or of bringing water from a distance, would be cut in two; that, even without the adoption of means for purifying the water, the quality of that furnished would be at once improved (for pumping could then be stopped during seasons of muddy or coal-dust-polluted water, and the water in the reservoirs would have longer time for sedimentation); that the minimum flow of the Schuylkill would once more greatly exceed the city's maximum draft upon it, and that the improvement and development of the supply would be brought well within the city's own means. I knew that, in restriction of *waste* (*not* of *use*), the city held, in her own hands, the key to the solution of her water problem, and that she required no assistance from the benevolent corporations which were seeking to relieve her of the the burden of her water works.

But my advocacy of the water meter merely alienated the good graces of citizens who were agitating for improvement of the supply, and who, fearing the ignorant clamor and opposition sure to arise upon the mention of the word "meter," did what they could to suppress all mention of the subject.

FILTRATION.

The quality of the supply has been already discussed. For improvement in this respect, I urged filtration, rather than resort to distant sources, and asked that an experimental filter plant be

established at one of the smaller pumping stations on the Schuylkill, and at the small Lardner's Point station, on the Delaware; these experimental plants to be made up each of several units, representing the best and most favorably known systems of the day. I was profoundly impressed with the facts that filtration was then in its infancy, and that each river and each set of conditions is a law unto itself, requiring careful separate study and experiment, in order to ascertain the best method of treatment.

This proposition met with but little if any more favor than the proposition to use meters. We were told that, if a beginning were made on one or two stations, without completing all simultaneously, the unfiltered districts would be up in arms; we were told that experiment would delay matters and that the entire work must be done as rapidly as possible, and we were asked whether filtration "had not passed the experimental stage." That was ten years ago, and it may be worth while to note, in passing, that the works are not yet completed, and that, although the Roxborough and Belmont works have now been in use for four or five years, the rest of the city, though long supplied with raw water, has not yet risen in insurrection.

There was much ignorant opposition to filtration in general, and the opposition has not yet died out. People still run about, saying that "they will never drink 'filtered filth,' " that "filtration may clarify water, but it does not purify," that "the bacteria in water can march, 1000 abreast, through the interstices between the grains in the sand filter," and that "Philadelphia will never have a proper water supply until she goes to the Delaware Water Gap for it."

It is indeed true that the bacteria are so minute that armies of them can pass between the sand grains; and, for that reason, the water first passed through a freshly-cleaned sand filter is allowed to run to waste—it is imperfectly purified; but, as the water passes between the sand grains, bacteria and organic matter are detached from the water and adhere to the sand grains. The upper portion of the sand layer thus soon teems with such matter, and, in this "Schmutzdecke" (filth-cover) the purification takes place by means of chemical and bacteriological processes which are, I believe, as yet only imperfectly understood; but it is perfectly well known that sand filtration, properly conducted, removes usually from 97 to 99 or more per cent. of the bacteria in the water, and

that its use is almost invariably attended by a very great reduction in typhoid and other water-borne diseases.

A slow filter (See Fig. 8) is simply a bed of sand resting upon layers of coarser sand, gravel and broken stone. These increase in coarseness from top to bottom, the open spaces, in each layer, being of course too small to pass the solid particles of the layer next above. The whole is underlaid by a system of drains, carrying off the filtered water. The raw water rests upon the sand above. In practice, of course, many details and appurtenances are required, especially for the proper regulation and recording of the flow through the filter.

As already remarked, the water, first passed through a freshly cleaned filter, is but imperfectly purified, and is therefore commonly run to waste; the real purification taking place in the upper portions of the sand bed, where a certain quantity of bacteria and other organic matter has been deposited by the water already passed. In a month or so (the time varying with the character of the water) the upper portion of the sand becomes so clogged, by the material thus deposited within it, that it can no longer pass the water with sufficient rapidity. The top sand must then be shoveled off, removed from the filter bed, and either wasted, or cleaned and replaced upon the filter bed, depending upon whether the supply of sand is so abundant as to make wasting the more economical process. In our case it is more economical to wash and replace it. The dirty sand is removed from the beds by means of hydraulic ejectors, and is washed in sand-washing courts by special apparatus provided for the purpose.

The rapid filter is often called the "mechanical" filter, because, in it, the washing of the sand (which is performed in the filter itself by reversing the flow of water through the filter, and sending it through under pressure), is often assited by revolving rakes, operated by machinery. In the rapid filter, a coagulant, usually alum or alumina sulphate, is commonly used. The alum is decomposed, the flocculent alumina settling slowly through the water, carrying down with it the bacteria and other organic impurities. These filters give results fairly comparable with those given by slow filters, and at much higher rates, measured in gallons per day per unit of filtering surface. They are in use in many places, with excellent results, although the necessity for the use of coagulants, in order to secure the high rates of filtration, is generally considered objectionable.

Formerly the rapid filter was always a cylindrical or nearly cylindrical wooden or steel tank, a form favorable to the operation of the revolving rakes; but, more recently, and notably at Little Falls, N. J., and at Harrisburg, Pa., the rapid filters are rectangular in plan; the revolving rakes are dispensed with; and, in washing the bed, it is agitated by currents of compressed air, forced upward through it. It is proposed to use filters of this type as "scrubbers" at Torresdale and at Queen Lane.

STATESMANSHIP.

I have mentioned the benevolent corporations (popularly known as "water snakes") which kindly came forward, in this hour of the city's distress, and graciously offered to lift (for substantial considerations) this water works incubus.

Among these stands out prominently the Schuylkill Valley Water Company, whose scheme was being victoriously rushed through Councils, when an exposure of bribery, on the floor of Councils, threw the fat in the fire, and the scheme passed silently from the gaze of men.

That such a trifle could be made to defeat such a scheme shows that the harmony, which has since reigned in the "organization," had not yet been effected. On the contrary, Mayor Warwick's administration found itself opposed by this organization (then only a powerful "faction"), which decreed that all appropriations for water works improvement should be held up until this faction came into supreme control. The result is seen in the following comparison of estimates for extensions and improvements, and the corresponding appropriations:

FOR EXTENSIONS AND IMPROVEMENTS.

	Estimates	Appropriations
For 1896	$2,484,150	0
For 1897	3,339,450	0
For 1898	3,735,050	0

We were told that the city had reached the limit of her borrowing capacity.

THE NEW ERA.

But, with the advent of Mayor Ashbridge, as the agent of the "organization," in April, 1899, the scene shifted. Real estate values were re-assessed, and it was announced that the city could borrow all the money needed for extensive improvements.

THE COMMISSION OF 1899.

Mayor Ashbridge called in a commission, consisting of Messrs. Rudolph Hering, of New York; Samuel M. Gray, of Providence, R. I., and Joseph M. Wilson, of Philadelphia. The resolution of Councils, under which these experts were appointed, provided that they were "to act in conjunction with the Director of the Department of Public Works, and the Chiefs of the Bureaus of Water and Survey." Under Colonel William Ludlow, Chief Engineer of the Water Department, in 1883-5, Mr. Hering, with an able corps of assistants, had made a very exhaustive study of the question of a supply of water from the Delaware Water Gap and other distant sources. In those days, the flood of light, since thrown upon filtration, had not been shed, and Mr. Hering was therefore quite justified in saying, in his final report, dated July, 1886: " * * nor would filtering or purifying the water of the Schuylkill or Lower Delaware give permanent satisfaction," and that "the only schemes worth investigating were those which bring to the city the water of running streams in the Schuylkill, Delaware, or Lehigh watersheds."

The commission of 1899, like that of 1883-5, was of course given an ample corps of assistants, and the entire summer of that year was devoted to the work, including several all-night sessions on the part of Mr. Hering.

This commission fully re-considered the subject of supply from a distant source, in the light of the surveys of 1883-5, and recommended, as will be seen below, "the adoption of that project by which the waters of the Schuylkill and Delaware Rivers, taken within the city limits, are purified by filtration."

The report was accompanied by plans showing, in a general way, the locations and dispositions of the several works proposed; but the working out of details was of course left to the administration which should construct the works.

The following table shows, in concise form, the estimates of the commission of 1899, of the costs, for construction and for operation, of distant supplies and of a supply by filtration. The cost of operation is given in dollars per annum and in cents per 1000 gallons delivered into reservoirs. It includes interest at three per cent. and depreciation:

	Gallons per day.					
	200,000,000			450,000,000		
		Operation			Operation	
	Construct'n	Annual	Per 1000 gal.	Construct'n	Annual	Per 1000 gal.
			Cents			Cents
Upper Perkiomen and Lehigh River tributaries	$33,410,000	$1,205,000	1.65	$66,740,000	$2,480,000	1.51
Delaware, near Water Gap	47,540,000	.....	.....	83,185,000	2,925,000	1.78
Slow filtration	10,973,591	1,227,373	1.68	34,154,680	2,971,801	1.81

Referring to these estimates, the experts say, in their "resumé and conclusions:"

"The estimates of cost have shown three important results:

(1) The original cost of any of the mountain water supplies is very great for the large quantities of water which the city requires.

(2) A filtered water supply can be obtained at a first cost which is within the present borrowing capacity of the city, and the plant can be operated at a cost which will not exceed the probable annual net earnings of the water works.

(3) The total annual cost of delivering the water into the city reservoirs, by either method, is about the same, and the annual earnings will cover the operation and extension.

In conclusion we recommend:

(1) The adoption of that project by which the waters of the Schuylkill and Delaware Rivers, taken within the city limits, are purified by filtration.

(2) The immediate improvement of the existing plant, in accordance with the detailed recommendations of our report.

The necessity for the second of these recommendations is manifest. Our reasons for the first are as follows:

The entire works can be built for a sum which the city can secure at this time through a loan.

A supply of pure water for the entire city can be obtained within a comparatively short time, and the city can thus at an early day be protected against a continuance of those diseases which are known to be caused by the present polluted water supply.

A filtered water supply, under skilful management, offers a greater security against the effects of accidental pollution of the water than is possible when the supply is taken from open, unprotected water courses.

Filtration can, without difficulty, be made to render the water thoroughly wholesome.

The two large rivers at Philadelphia, or even the Delaware River alone, can furnish at all times a quantity of water sufficient for a very large city."

Fig. 6 is plotted from the foregoing estimates of cost of filtration. The estimates are, respectively, for a supply of 200,000,000 gallons per day, which the Commission considered "a very liberal allowance" for the population (say 1,300,000) of that time, and for a supply of 450,000,000 gallons per day, which the Commission believed would be required by a population of 3,000,000 persons.

Upon Fig. 6, I have scaled the probable costs, for construc-

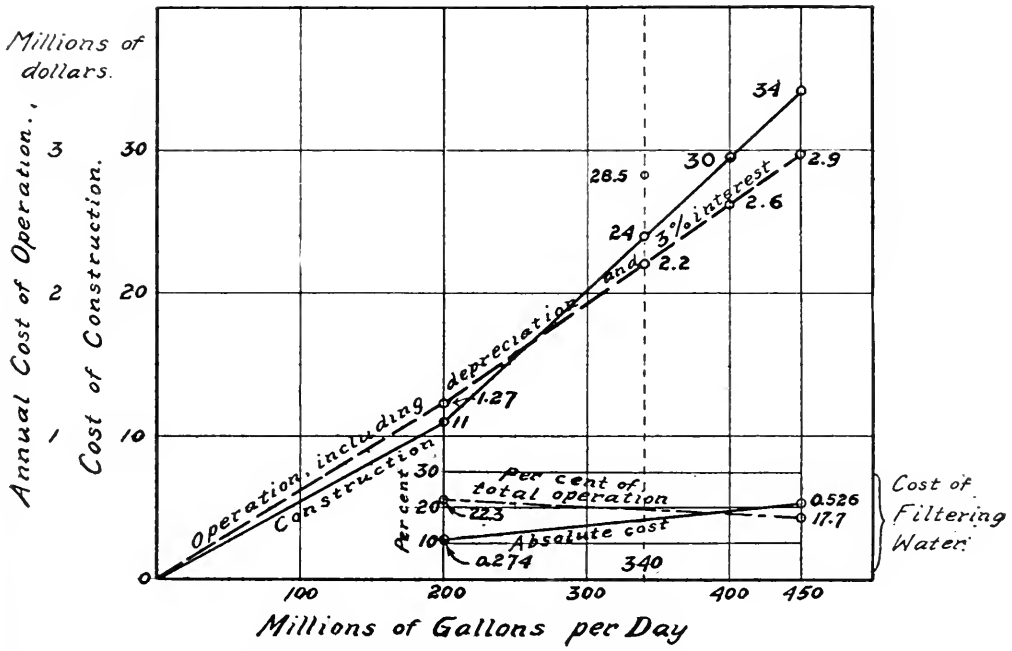


Fig. 6. Estimated costs, for construction and for operation, of slow filtration plants, for Philadelphia; from report of Commission of 1899.

tion and of operation, for 400,000,000 gallons per day (twice the smaller amount contemplated) and for 340,000,000 gallons per day (the capacity of the works as it is expected to be in 1909).

The results for 400,000,000 gallons per day show that, by doubling the consumption, we may expect to more than double the cost of operation, and to considerably more than double the cost of construction.

The results for 340,000,000 gallons per day show that, according to the Commission's estimates, the cost of operation for the entire works next year should be about $2,200,000, of which the

"cost of filtering water" alone should be about $400,000, or a little over 18 per cent. of the whole.

As nearly as we can judge, by scaling from the Commission's estimates, the entire cost of reconstruction, for the works as they will be in 1909, and capable of handling 340,000,000 gallons per day, should have been about $24,000,000. As seen below, the cost of work now finished or under contract, plus estimated cost of work not yet placed under contract, as given me by Mr. Fred. C. Dunlap, the present Chief of the Bureau of Water, amounts to about $28,250,000. Considering that the new works are, in many respects, far more elaborate than the Commission of 1899 ventured to suggest, I regard these figures as indicating that the total cost has been considerably less than might properly have been expected for works of that capacity.

In the body of their report the Commissioners said: "We earnestly recommend the introduction of meters for the City of Philadelphia;" but, in their "résumé and conclusions," the meter was not mentioned, and the shortage of supply was attributed to "the lack of effective pumping machinery, and to the insufficient capacity of the distributing system." The works are planned for a consumption of 150 gallons per capita per day, or only 19 gallons per capita per day less than the Commission's estimate of the actual consumption at that time.

The works have cost, for construction, and will cost for operation, more than double what would have sufficed for a lavishly ample supply, and the people will nevertheless be on short rations.

The building of works of such dimensions was in accordance with the expressed wish of Mayor Ashbridge, that the works might be made sufficient for the next fifty years. A layman can hardly be expected to conceive the rate at which the art of water supply is advancing, or the consequent folly of building for posterity, where, as in our case, there is no necessity for so doing. A great aqueduct is not easily enlarged, and it should therefore be built of a capacity considerably greater than is required by present needs; but the ground, adjoining the Torresdale filter plant, is such that the plant may be increased, a bed or two at a time, as occasion requires. There was therefore no excuse for building for posterity. It merely saddled posterity with a plant which it may not find the best for its needs. However, personal ambition, and the needs of contractors, cannot be expected to be always in harmony with the best interests of the public.

For the immediate future, the Commisison contemplated drawing from the two rivers as follows:

From the Schuylkill—

	Gallons per day.	
At Belmont	27,000,000	
At Roxborough	15,000,000	
At Queen Lane	58,000,000	
At East Park	50,000,000	
		150,000 000
From the Delaware—		
At Torresdale		50,000,000
		200,000,000

The Commission recommended the abandonment of the Lardner's Point station, on the Delaware, and the building of a 50,000,000 gallon station and filter plant at Torresdale.

It will be noticed that this distribution reduced the Schuylkill's proportion of the total supply from 90 to 75 per cent., and all future increase of the supply was to be taken from the Delaware.

The turbine pumps at Fairmount were to be connected with the steam pumps at Spring Garden, for the relief of the latter when the stage of the river would permit.

A rapid filter plant was to be established at East Park reservoir, but slow filtration was to be used for all the rest of the supply.

Where practicable, the existing reservoirs were to be used for the sedimentation of the raw water, preliminary to filtration, except that a portion of their capacity was to be set apart for storage of filtered water. It was considered desirable that the raw water should have at least twenty-four hours for sedimentation, and that there should be stored a half-day's supply of filtered water. All filters and all reservoirs for filtered water were to be covered.

At East Park filter plant, two twelve-million-gallon engines were to be installed, to pump into the Queen Lane district.

At Belmont, the old reservoir was to be used for sedimentation, and it was suggested that, with increase of population west of the Schuylkill, its capacity would have to be increased by the construction of a similar reservoir alongside of it.

THE ADOPTED PLAN.

The plan, actually followed, differed radically, in several important respects, from that recommended by the Commission of 1899, but resembled it in the adoption of filtration and in the diminution of the proportion of water taken from the Schuylkill. On the other hand, rapid filtration has been entirely discarded.

The total capacity of the works, when completed, is expected to be 340,000,000 gallons per day, of which about one-third, or say 115,000,000 gallons, will be taken from the Schuylkill.

The Fairmount works are to be abandoned; the East Park reservoir will be used for the storage of a reserve supply of raw water, and the Spring Garden pumping station will be kept in reserve and used when necessary for keeping up said supply.

The Queen Lane station and reservoir, completed about 1895, are unique in that they form a complete system in themselves; that they were built *de novo*, and not in connection with, or even in proximity to, any other works; and that they have remained without additions. It was at one time proposed to remove its four pumps (as well as several others of the Schuylkill pumps) to the New Delaware station at Lardner's Point; but only one (a large Southwark engine from Roxborough, taken to the old Lardner's Point station) has been moved over, and the Queen Lane pumps are to remain where they are.

Various fates have impended over the head of the Queen Lane reservoir. Immediately after its construction, it got into bad notoriety by leaking as soon as water was turned into it. This afforded a fine opportunity for the opposition newspaper, which bristled with awful cartoons, showing the water gushing in big streams from the structure. During my administration, 1895-9, it, like the Roxborough reservoir, was re-lined with asphalt, and its behavior has since been wholly exemplary; but this did not prevent the chairman of the Water Committee of Councils from remarking, in Committee, a year or two later, that, if the Queen Lane basins had ever been made to hold water, he had not heard of it; and one of the patriarchs of Councils actually introduced a resolution looking to the abandonment of the reservoir and the utilization of the site for building lots. The experts of 1899 recommended a slow filtration plant, to be placed on ground just

north of the reservoir. This would have involved the destruction of the fine old Revolutionary Smith mansion, at which Washington visited. This project was abandoned, and it was later again proposed to abandon the reservoir itself; but it is now intended to build preliminary and main filters over the north basin, the lower part of which is to be the clear-water basin.

At Belmont, three new pumps and additional boilers have been built, and the whole plant is enclosed in a fine new house. In connection with the Belmont filter plant, located practically as the commission proposed, a large new reservoir, for sedimentation, has been built, and the old reservoir is used for storage of filtered water. Preliminary filters have been built.

For Roxborough, the commission of 1899 proposed a filter plant in connection with the upper or larger reservoir only; but filter plants, each with its clear water basin, have been constructed at both reservoirs, and four large new pumps, with new boilers and a new house, have been added to the pumping station at the river.

As already stated, the commission of 1899 proposed a fifty-million-gallon pumping station and filter plant at Torresdale, and the abandonment of the old station at Lardner's Point; but a filter plant of sixty-five beds (fifty-five of which are shown in Fig. 7, with a combined filtering area of fifty acres, and 175,000,000 gallons* daily capacity, has been finished at Torresdale; and the water, delivered by this plant to its clear-water basin, is thence conducted, by gravity, through a tunnel-conduit, 10 feet 7 inches in diameter, 100 feet below ground and two and one-half miles long, to the new monster pumping station, built near the old pumping station at Lardner's Point, which is to be retained in service.

Fig. 8 shows this conduit (one of the most important features of the new plant) in plan and in profile, and, in profile, the 6-ft. brick conduit, built by Latrobe in 1800 for the City's first water works. This old conduit carried the Schuylkill water from the first or Schuylkill pumping station, down Chestnut Street and up Broad Street, to the second pumping station, at Center Square.

---

*The "scrubbers," or preliminary filters, shown in Fig. 7 and now approaching completion, are expected to raise the capacity to 240,000,000 gallons per day, as in the table below.

The profile shows the two structures to scale and at their relative elevations, and gives their dimensions, volumes and capacities.

Both tunnels sloped upward, for convenience of flushing. In the Latrobe tunnel, the flow was by gravity, the slope of the water

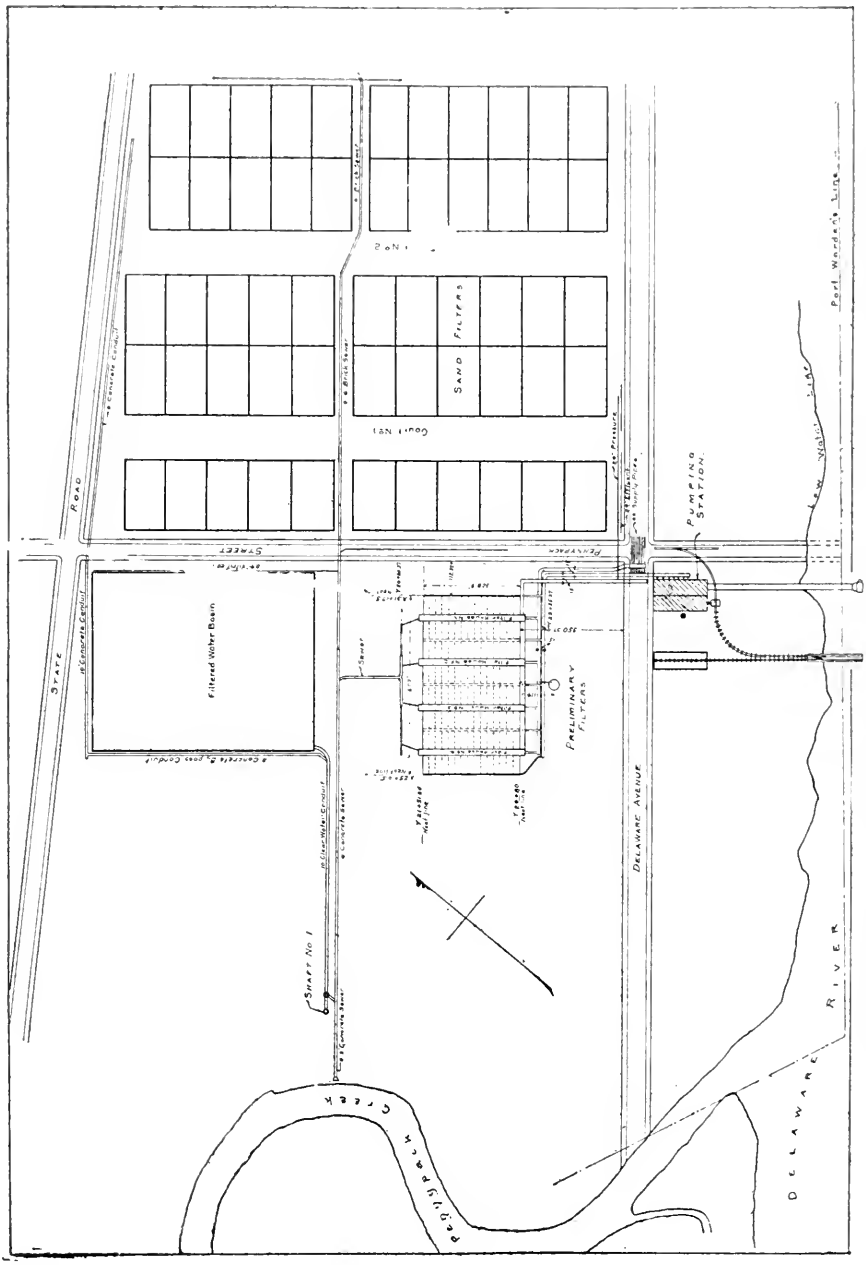


Fig. 7. Plan of Torresdale Filter Plant, showing pumping station, preliminary filters, 55 of the 65 slow filters, filtered water basin, and beginning of Torresdale conduit

surface, from 22d and Chestnut Streets to Center Square, of course producing the flow notwithstanding the slope of the axis of the conduit in the opposite direction. In the new tunnel conduit, driven by Mr. John W. Hill, then Chief Engineer of the

Bureau of Filtration, the flow is caused by the difference of elevation in the clear water basin at Torresdale and in the pump well at Lardner's Point.

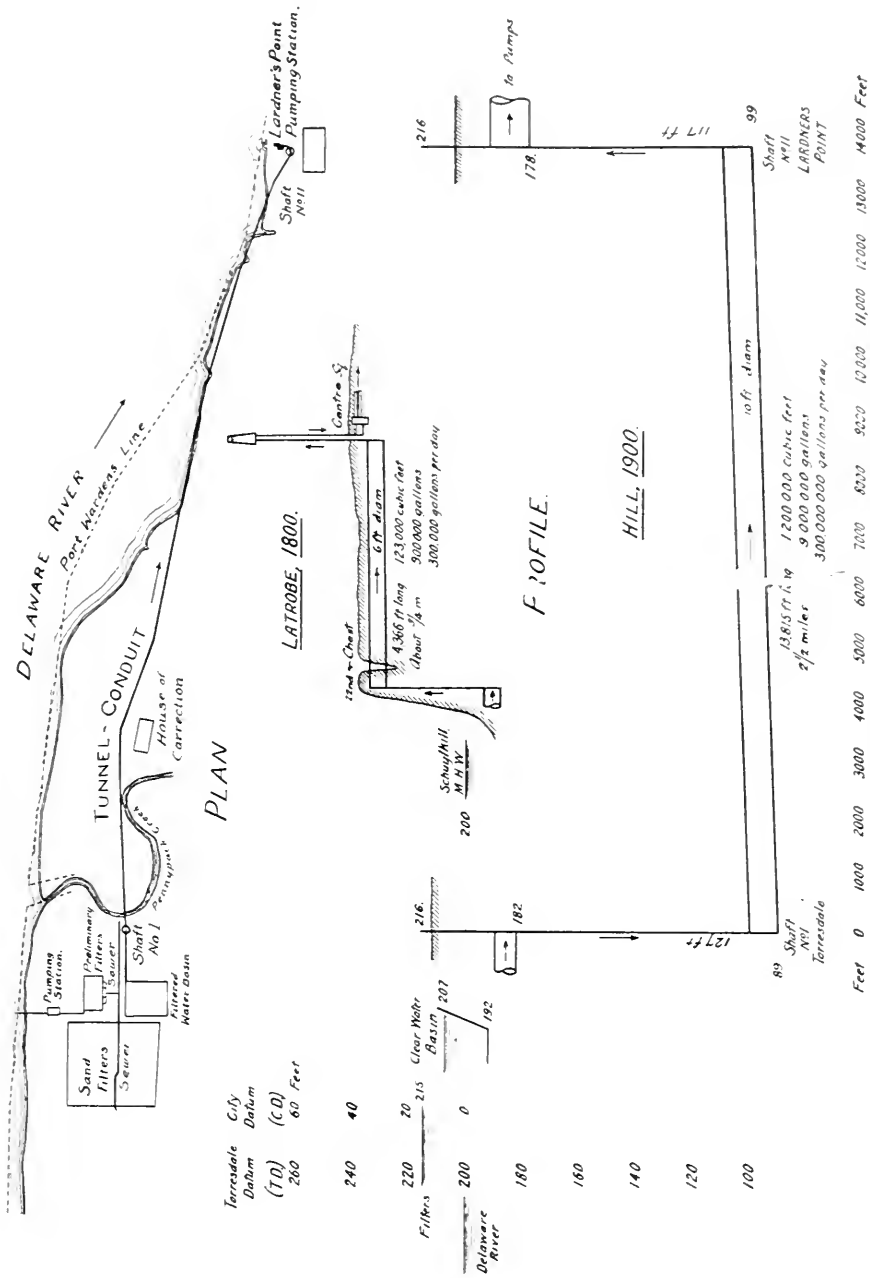


Fig. 8. Plan and profile of Torresdale tunnel conduit of 1900, and profile of conduit of 1800.

Like the Queen Lane reservoir, Mr. Hill's tunnel at once found its way into notoriety through leakage. When this tunnel was emply, it was found that a good deal of water leaked into it; but the conditions were, of course, altogether abnormal. When the tunnel is in service, it is full of water under a pressure presum-

ably greater than that of the ground water outside, so that we may expect a small loss of filtered water, from the tunnel into the surrounding ground. The leakage mentioned occurred when the tunnel was emptied, and the ground water was forced into it by an unopposed external head of probably about 100 feet. In view of this, and knowing something of the difficulty of making large structures watertight against heavy pressure, I could not consider the resulting leakage remarkable; but it was used, to good effect, by some of the more active opposition newspapers, and the matter made its appearance in court, where the bulk of the expert testimony offered pronounced the work excellent, confirming the impression which I had formed upon walking through it, at the invitation of, and in company with, Mr. Hill.

Major Cassius E. Gillette, who succeeded Mr. Hill, drilled very many holes through the tunnel lining, and, through these holes, forced grout into whatever spaces had been left between that lining and the surrounding rock. I believe that this treatment materially improved the condition of the structure.

The new pumping station at Lardner's Point is perhaps the largest on earth. When completed, it will contain twelve vertical triple-expansion pumping engines, each of twenty million gallons daily capacity, pumping against a head of over 200 feet, and supplied with steam by 26 boilers, including 14 water-tube boilers, with mechanical stokers. The pumps and boilers will be sheltered by two great engine houses and two boiler houses, of uniform design, already finished.

At Belmont, at both Roxboroughs and at Queen Lane, the raw water is delivered into the sedimentation basins directly by the high-lift pumps at the river; but at Torresdale a special low-lift pumping plant will lift the river water to the "scrubbers," whence it will flow to the filters, thence to the clear-water basin, and thence, through a short conduit and vertical shaft No. 1, into the tunnel. At Lardner's Point it will rise, through shaft No. 11, to the pump wells of the Lardner's Point pumps.

From Lardner's Point, the filtered water will be sent, by direct pumpage (unobjectionable, of course, with filtered water) into the distribution. The pumping mains are connected with a new reservoir at Oak Lane, but this will serve merely as a stand pipe on the pumping mains, preventing rapid fluctuations of pressure.

PRELIMINARY FILTERS.

An important feature, in which the adopted plan differs from that of the commission of 1899, is the introduction of preliminary filters or "scrubbers."

The slow sand filter, used at all the Philadelphia works, is ordinarily expected to work at a rate of between two and three million gallons per acre per day; but it has been found that, by passing the water first through the relatively coarse filtering material of the scrubbers, and at a correspondingly rapid rate, before admitting it to the main filters, the capacity of the latter can be greatly increased at comparatively small expense, and the "scrubbers" occupy only a small area of ground relatively to that required for the main filters.

At Lower Roxborough, a "scrubber" plant has been built for the Bureau by Mr. P. A. Maignen, of this city. In it, the raw water passes vertically upward, first through a layer of large stones, then through layers of coke, broken into pieces of gradually decreasing size, and finally through a bed of sponge. It then flows to the main filters. From time to time the sponges are washed in machines of the type used in laundries.

At the Belmont "scrubber," also built by Mr. Maignen, the water passes horizontally through beds of coke, and finally vertically through a bed of fine coke breeze.

Both these "scrubber" plants are said to be giving excellent results.

For the "scrubbers" at Torresdale and Queen Lane, the Bureau proposes using rapid filters, of the rectangular type used at Little Falls, N. J., for water purification. The Torresdale "scrubbers" will consist of 120 such filters.

GENERAL ARRANGEMENT.

The Philadelphia filters are all of the usual covered slow type; the roof being formed by flat groined arches, resting upon square pillars, the feet of which are connected by flat invert arches; all as shown in Fig. 9, which represents the construction at the Lower Roxborough plant.

At Belmont and at Lower Roxborough, the water is forced, by the pumps at the river, from the river directly into the sedimentation reservoir, whence it flows, by gravity, through the following course:

(1) Sedimentation reservoir
(2) Scrubbers
(3) Filters
(4) Clear water basin
(5) Distribution;

as indicated in Fig. 10, which shows a rude plan of the Lower Roxborough filter plant.

At Upper Roxborough, the capacity of the sedimentation reservoir is so great, and the sedimentation therefore so effective, that scrubbers have been omitted.

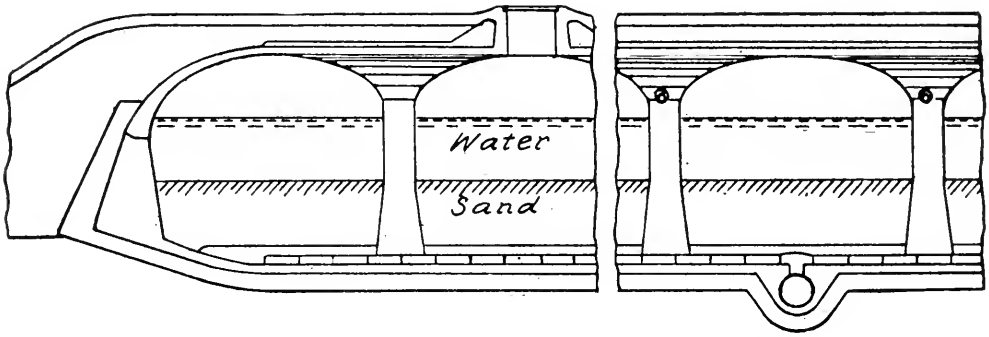


Fig. 9. Vertical section of a slow filter bed, Lower Roxborough.

At Torresdale, the Commission of 1899 proposed sedimentation basins, close to the river. To these basins the river water was to be lifted directly by low-lift centrifugal pumps. The present design (Fig. 7) omits sedimentation basins and substitutes scrubbers. The clear-water basin is at a lower level than the distribution, to which, of course, the filtered water could not flow by gravity. It is therefore conducted through the Torresdale conduit, two and one-half miles, to the Lardner's Point pumping station, which forces it directly into the distribution. The reservoir at Oak Lane serves merely as an enlarged stand pipe upon the pumping main from Lardner's Point.

At Queen Lane, the system will have each of the five features mentioned above, and, in addition, low-lift pumps, raising the water from the sedimentation reservoir (the south basin of the

existing reservoir) to the scrubbers, which will be placed over the north basin of the same reservoir.

The table, p. 392, gives, in concise form, a comparative statement of the approximate dimensions and capacities, and the functions, of the several pumping stations, reservoirs and filter plants, as they were in 1898, just before the inauguration of the era of fil-

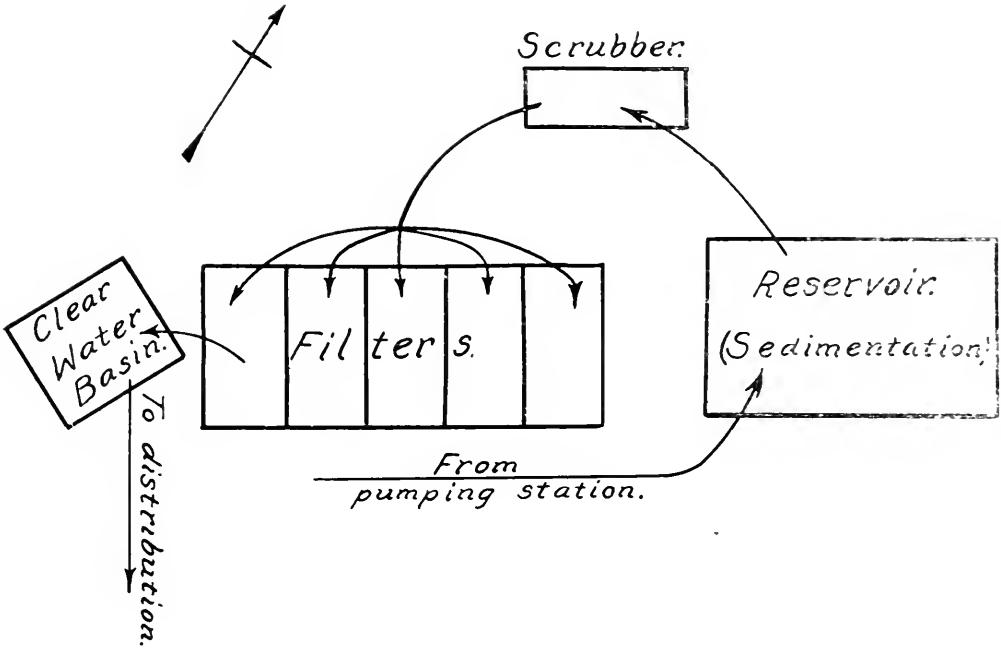


Fig. 10. Sketch plan of Lower Roxborough Filter Plant, showing progress of water from pumps to distribution.

tration, and as they are to-day, or will be when completed, probably early during the coming year. The daily capacities of pumping stations and of filter plants, and the holding capacities of reservoirs, are stated in millions of gallons, to the nearest million. Under pumps, "to Fmt reservr," etc., means "*Pumping to* Fmt reservoir," etc.

PUMPING STATIONS, RESERVOIRS AND FILTER PLANTS, 1898 AND 1908-9.

(The approximate daily capacities of pumps and filter plants, and contents of reservoirs, are stated in millions of gallons, to the nearest million.)

Plants.	*1898.*	*1908-9.*
Fairmount Pump'g Sta.,	7 pumps, 33, to Fairmount Res.	———
Fairmount Reservoir,	26, raw water.	———
Sp. Garden Pump'g Sta.,	9 pumps, 170, to East Park Res.	8 pumps, 150, in reserve, to E. Park, as required.
East Park Reservoir,	689, raw water.	689, raw water.
Belmont Pump'g Sta.,	4 pumps, 38, to George's Hill Res.	6 pumps, 67, to New Belmont Res.
George's Hill Reservoir,	40, raw water.	40, clear water.
New Belmont Reservoir,	———	75, sedimentation.
Belmont Filter Plant,	———	Scrubbers. 18 beds, 50.
Queen Lane Pump'g Sta.,	4 pumps, 80, to Queen Lane Res.	4 pumps, 80, to Queen Lane Res.
Queen Lane Reservoir,	383, raw water.	South basin for sedimentation. North basin for clear water.
Queen Lane Filter Plant,	———	Low-lift pumps, over N. basin. Scrubbers, over N. basin. 22 beds, 80, over N. basin.
Roxboro' Pump'g Sta.,	3 pumps, 25, to Roxboro' Res.	9 pumps, 52, to Roxboro' Res.
Lower Roxboro' Filter Plant,	13, raw water.	13, sedimentation.
Lower Roxboro' Reservoir,	———	Scrubbers. 5 beds, 10.
Upper Roxboro' Reservoir,	147, raw water.	147, sedimentation.
Upper Roxboro' Filter Plant,	———	8 beds, 15.
Torresdale Filter Plant,	———	Low-lift pumps. Scrubbers. 65 beds, 240.
Torresdale Conduit,	———	10′7″ diam., 2.5 miles long, carries clear water to Lardner's Point.
Lardner's Pt. Pump'g Sta.,	3 pumps, 42, to Wentz Farm Res.	16 pumps, 297, direct pump'ge, clear water.
Wentz Farm Reservoir,	36, raw water.	36, clear water.
Oak Lane Reservoir,	———	On pumping mains from Lardner's Point.

THE COST.

The cost of construction, as given me by Mr. Fred. C. Dunlap, the present Chief of the Bureau of Water, is approximately as follows:

Work finished or under contract	$26,000,000
Other work, estimated	2,250,000
Total	$28,250,000

This cost is divided approximately as follows:

Delaware River	$14,250,000
Schuylkill River	7,000,000
Distribution system	5,500,000
Repairs to pumping stations	1,500,000
Total	$28,250,000

CAPACITY.

The consumption, in 1907, as deduced from plunger displacement, was about 300,000,000 gallons per day. The works, when completed, will have a capacity of 340,000,000 gallons per day, probably rather less than the increased demand of that time. These 340,000,000 gallons would be ample for a population of five million persons, but they will prove a scant supply for our one and one-half millions, because our people prefer to be robbed by a small minority, which wastes far more that the decent majority uses.

COMPLETION.

The Roxborough works, supplying 25,000,000 gallons daily, have been furnishing filtered water since 1903; and the Belmont works, 40,000,000 gallons* daily, since 1904. The Torresdale works are now supplying about 110,000,000 gallons daily to the northeastern portion of the city. The central portion of the city, still supplied with raw water, may be said to be bounded by the

*With scrubbers, 50 million.

two rivers, by Spring Garden Street, east of Broad Street, and by Allegheny Avenue west of Broad Street.

It is expected that the Torresdale works will be finished during the current year, and the Lardner's Point plant in 1909, or about ten years after the inauguration of Mayor Ashbridge. The work for Queen Lane reservoir is not yet under contract, and no time is set for its completion.

For information respecting changes made since my resignation from the Water Bureau in 1899, I am indebted principally to the present Chief of the Bureau, Mr. Fred. C. Dunlap.

THE BORAX INDUSTRY IN 1906.

The entire output of borax in the United States is derived from San Bernardino, Inyo, and Ventura counties, California, and up to and including 1906 the greater part of it has come from San Bernardino County.

Until 1903, the annual statistics of production collected by the United States Geological Survey were based on the quantity and value of the refined product, but since then crude borax has been taken as a basis, as the prepared borax is essentially a manufactured product. The quantity of crude materials mined (borate of lime or colemanite), with varying richness of boric acid, is readily ascertained, and the value of the crude material is therefore calculated according to the percentage of boric acid it contains.

The total output of crude borax for the year 1906 was 58,173 short tons, valued at $1,182,410, as against 46,334 short tons, valued at $1,019,154, in 1905, an increase in 1906 of 11,839 short tons in quantity and of $163,256 in value. The imports of borax, boric acid, and borates into this country in 1906 were valued at $62,979, an increase of $20,179 over the value of the imports for 1905, which amounted to $32,800.

The cost of crude borax varies materially with different producers, owing to local conditions, length of haul to railroad, etc. Some of it is also semi-refined before shipment and subsequently fully refined at points far distant from those of production.

Statistics of the production of borax in the United States in 1906, prepared by Charles G. Yale, are published by the United States Geological Survey in an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," which is now ready for distribution.

Notes On Theory and Practice of Evaporation.

By Philip B. Sadtler, S.B.

(*Continued from vol. clxvi, p. 296.*)

PRACTICAL CONSIDERATIONS IN THE DESIGNS OF EVAPORATORS.

Data Necessary for Designing:—The successful designing of an evaporator is dependent first on the recognition of certain chemical and physical facts relating to the substance to be evaporated; second, on whether or not due regard is paid to certain thermal and thermo-dynamic principles involved, and third, on certain mechanical features that arise in the construction. It is not to be supposed that either an engineer, familiar with the best boiler practice, or a chemist, familiar with laboratory or open pan evaporation in the works, could successfully design a Multiple Effect Evaporator. But certain facts in regard to design should certainly aid either a chemist or engineer in procuring the proper design or making a purchase.

As the principal purpose of an evaporator is to concentrate a solution of some sort, it will be readily seen that the chemical and physical laws governing concentrated solutions will be of importance. These are only known qualitatively and the quantitative laws which govern the chemistry of dilute solutions are inapplicable.

As most measurements of the concentration of solutions in the works are made with a hydrometer we generally speak of concentrating between certain limits in degrees, Beaumé, Twaddell, Brix, Salinometer, or Specific Gravity. It is, therefore, necessary to obtain or devise tables or curves showing the relation of these units of concentration with the percentage of solid matter in solution. The purpose of this is to obtain accurate information as to the actual amount of water that is going to be evaporated in a unit of time. This is especially important in cases where the

vapor arising from the solution is the source of heat in the succeeding effect of the evaporator.

Of equal, or greater importance, is a table or curve for a given solution which shall accurately show the relation between the boiling point of the solution and its concentration. It will be shown below, that the boiling point of a solution at any period of its progress through the evaporator has a direct bearing upon the size of the evaporator. A boiling point curve is generally obtained by taking simultaneous readings upon a hydrometer and thermometer, while boiling a solution actively under atmospheric conditions. This may best be accomplished in a laboratory where accurate means of determination are provided. After this curve is obtained a correction should be made for temperature at boiling to bring the hydrometer readings to the same temperature standard.

In cases where a substance is intended to precipitate from solution, during the process of evaporation, there should be used in conjunction with the above table also a table of solubilities of the substance at different temperatures.

The thermodynamic data necessary consist of the regular steam engineer's tables, showing the relations between temperature, pressure, heat of liquid, heat of vaporization, etc.

There are other chemical and physical data of which account must be taken in designing. The more information obtainable in regard to possible incrustation and scaling of heating surface, the clearer will be the idea as to what mechanical features to introduce for the removal of scale and as to what excess capacity to allow for this contingency. As in boiler practice, one of the greatest sources of annoyance is the deposition of gypsum on the tubes. This annoyance is encountered in the salt industry especially; due to the peculiar solubility relation of gypsum, it is found more expedient to evaporate at low temperature with large heating surface, thus minimizing the scale. Another similar case is that of soda washings in pulp mills, where cooking liquor is evaporated for soda recovery. If the lime used in the course of the process is high in silica and alumina, these find their way to the evaporator and deposit in a dense fibrous scale. If such possibilities as these are to arise, it is found expedient to have the heating surface in excess of the calculated area and easily removable from the evaporator for cleaning purposes. Moreover, it should be removable

where corrosion is expected. There are some chemical solutions which corrode iron, at the higher temperatures but are inactive at lower temperatures. In these cases the heating surface bears the brunt of the destruction in the evaporator.

Another important question is, as to the nature of a solution's activity under boiling conditions. In other words, does the boiling solution tend towards entrainment or foaming, or spattering. These points must be known beforehand, as they decidedly influence the proportioning of the evaporator. Figure 3 shows a

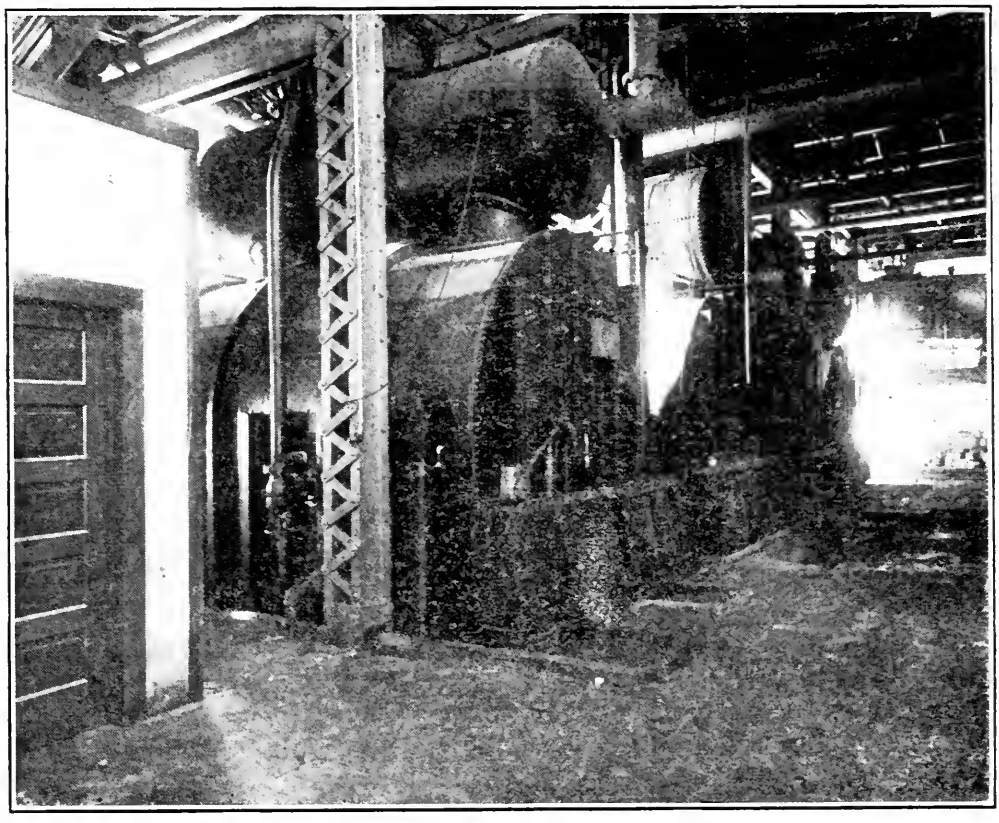


Fig. 3

large cylinder, known as a *catch-all*, placed above the vapor dome, in order to catch entrained sugar solution carried along with the vapor by the force of the ebullition in the evaporator. The sectional area of this cylinder, being greater than that of the vapor pipes leading off from the evaporator, there is caused a diminution of the rate of flow of steam and a consequent dropping out of the entrainment.

Figure 4 shows an evaporator built to evaporate pulp mill wash

waters containing large amounts of resinate of soda. This is very foamy when in process of ebullition. In designing this apparatus it was found best to build the tubes up in four banks, so that the upper part of the heating surface would kill the foam. Thus, when the apparatus is in operation the liquid level is rather low and the two upper banks heat the foam arising from the lower part and cause it to subside.

Figures 5, 6 and 7 show different views of an evaporator used on sugar and glucose, having two banks of tubes. The floor

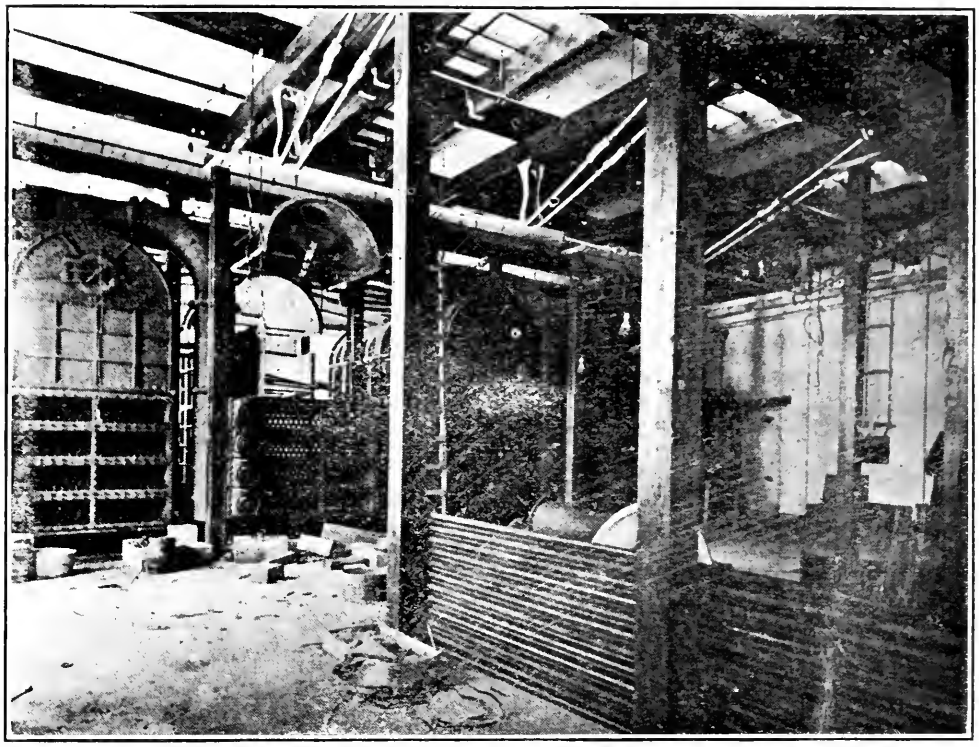


Fig. 4

under the upper bank "B" acts as a baffle to decrease the entrainment from the lower bank "B;" the vapor arises from the lower level "K" and passes through the side vapor pipes "CC" into the vapor space. By this method the entrainment is decreased and the apparatus has a larger evaporative capacity for its size.

Calculation of Heating Surface:—The amount of heating surface necessary, depends primarily on the amount of water to be evaporated, the number of effects desired, the initial steam pressure, the boiling points of the solution to be evaporated, and the

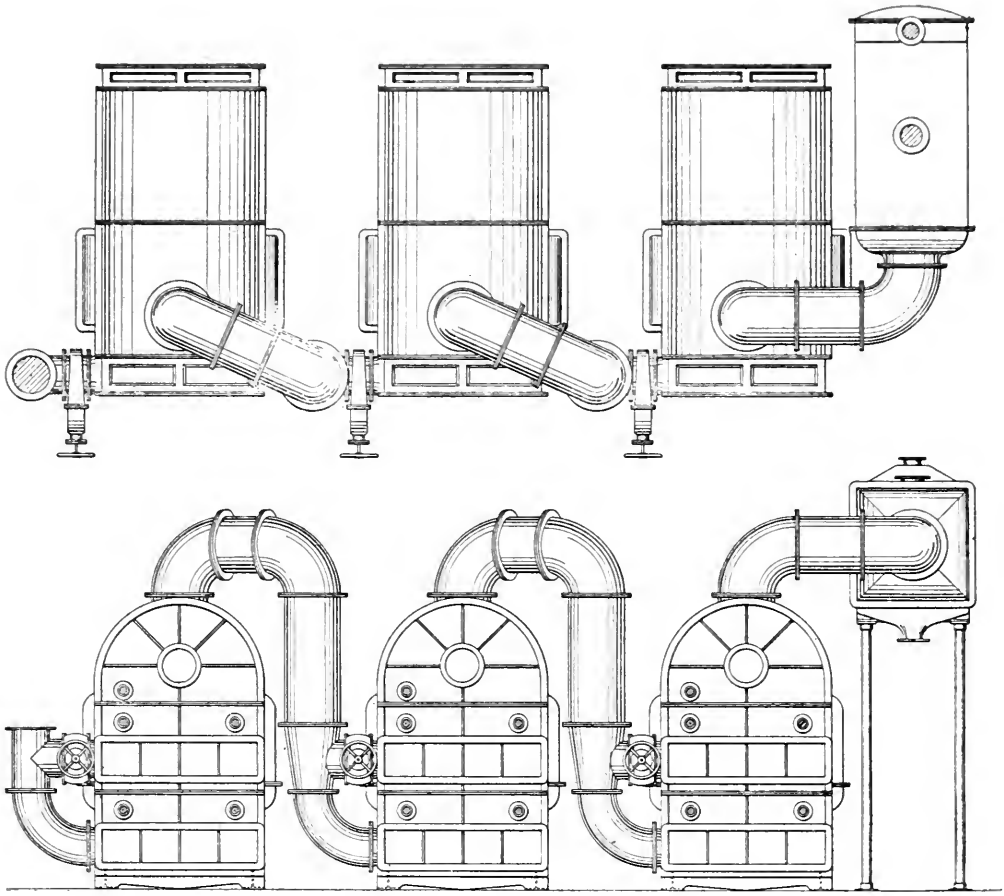


Fig 5

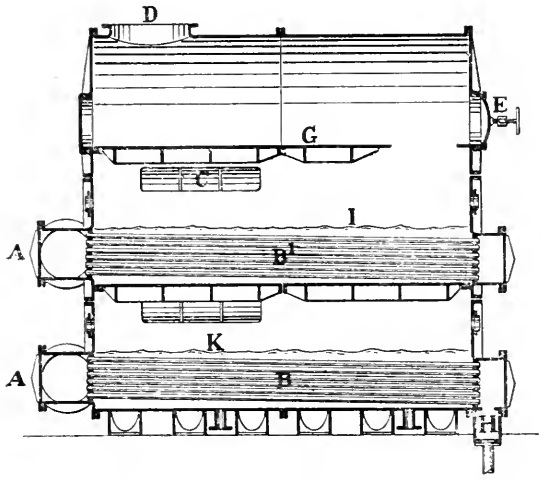


Fig. 6

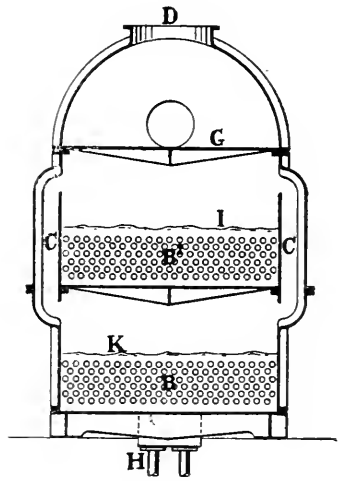


Fig. 7

evaporative factor for a given type of machine, and for a given solution to be evaporated.

In calculating the amount of water to be evaporated, it is merely necessary to obtain from tables or analysis, the percent of solids in the dilute and the concentrated liquor. From this we can obtain the amount of water to be evaporated. When the number of effects, in which the evaporation is to be done, is determined, a calculation should be made of the water evaporated in each effect and from that, what the concentration should be maintained at, in each effect. When these concentrations are known the corresponding boiling points should be found from a good table of boiling points or by experiment. The *degrees* of *excess boiling* temperature is the total of each of these boiling points less 212°F. In other words, if the boiling points in three effects are respectively 214°, 220°, and 236°, the excess boiling temperature is $(214-212)+(220-212)+(236-212)=34°$.

From the steam tables of pressure and temperature the *total temperature range* should be found. This is the temperature corresponding to initial steam pressure minus the temperature of steam pressure corresponding to vacuum maintained in the last effect.

The evaporative factor is a quantity constant derived from ex-*effective range*. This divided by the number of effects equals the *average effect difference*.

The evaporator factor is a quantity constant derived from experience and operative tests on the type of apparatus best adapted and on the given class of liquor to be evaporated. Probably the same factor would hold, for instance, on all horizontal submerged tube evaporators of the general type of those under discussion and would hold for either caustic soda solutions or carbonate of soda solutions. In fact the same constant quantity could be used, and has been used, in designing evaporators for a large range of inorganic chemical solutions, such as sodium chloride, sodium hydrate, sodium carbonate, sodium sulphate, sodium phosphate, sodium acid phosphate, sodium thiosulphate, potassium chloride, potassium hydrate, ferrous sulphate, calcium acetate, etc., etc. However, in cases of tannic acid, sugar, glucose, glycerine, black liquor, or resinate of soda, packing house tankage, garbage tankage, etc, somewhat different conditions obtain and the factor varies. The factor also differs slightly for different materials for

the heating surface. That for copper or aluminum being distinctly higher than that for iron.

To specify the units on which this factor is generally based we might say that it is expressed as gallons of water evaporated, per square foot of heating surface per degree difference in temperature per hour.

If C = evaporative factor
E = average effect difference
W = gallons evaporated
T = time in hours during which evaporation proceeds
S = square feet of heating surface

$$C = \frac{W}{E \times T \times S}$$

Hence, if we find from experience or trial tests the value of C and if we calculate E and W, as explained above, it is easy to obtain the required heating surface.

(To be continued.)

GOLD AND SILVER OUTPUT OF COLORADO IN 1906.

Statistics collected by the United States Geological Survey show that Colorado still outranks any other State or Territory in the Union, including Alaska, in the production of the precious metals, despite the fact that the gold production of the State in 1906 fell short nearly $2,000,000 of that of 1905, the precise figures being, output $23,210,629, decrease $1,813,344.

More than half of the total gold of the State is derived from the telluride veins of Cripple Creek in Teller County. San Miguel free-milling ores contribute nearly $2,500,000. The smelting ores of Leadville, in Lake County, yielded $1,500,000 and the partly free-milling Gilpin County ores over $1,000,000. San Juan County and Ouray County both closely approached the million-dollar mark. Important diminution in the output is recorded in Teller and Ouray Counties, but this was partly offset by gains in San Miguel and other counties. Siliceous and dry ores formed 67 per cent. of the total tonnage and were the source of over 96 per cent. of the gold product. The placer output is comparatively small. The outlook for 1907 does not indicate the probability of great increase, if any.

The production of silver, 12,216,830 ounces, showed an increase of 717,523 ounces. The smelting ores of Lake County led in the output, with nearly 4,000,000 ounces, while in their order Pitkin, San Miguel, Mineral, San Juan, Ouray, and Clear Creek Counties are next in importance, the first three exceeding the million mark. A higher price increased the value of the product. The increase is due chiefly to the veins of San Juan, San Miguel,

and Mineral Counties. On the other hand, the yield of the Leadville and Aspen deposits diminished.

About half of the silver product of the State is derived from silicious or dry ores, 28 per cent. from lead ores, and 17 per cent. from zinc or zinc-lead ores. No great change is expected in the production of silver for 1907.

The Geological Survey published during December an advance chapter from "Mineral Resources of the United States, Calendar Year 1906," containing a discussion by Waldemar Lindgren, geologist, of the gold and silver production of the United States in 1906.

DOMESTIC PRODUCTION OF BISMUTH.

The United States has been but a small producer of bismuth ores, and these have been shipped abroad for refining. Meanwhile this country has imported refined bismuth to a much greater value than that of its exports of the raw material.

The only bismuth produced in the United States in 1906, so far as reported, was derived from two mines at Leadville, Col., whose output was 8334 pounds, valued at $12,500. The imports of bismuth during the year amounted to 254,733 pounds, valued at $318,452, but no record was kept of the importation of bismuth compounds.

Bismuth ores are known to occur at a number of other localities in Colorado besides Leadville; in southeastern New Mexico; in southern California; on Charley Creek, 35 miles north of Nome, Alaska; at Hailey, Idaho; on Reese River, Nevada; and west of Salt Lake, Utah; but production was not reported from any of these deposits in 1906.

The refining of bismuth does not appear to be difficult, but the large smelting companies do not care to undertake so small a business, while the smaller firms apparently do not wish to antagonize the foreign firms, who now control the trade. Some lead ores carry bismuth, and when lead is refined electrolytically the bismuth remains in the residual mud. It is thought that the lead refineries using this process may turn out some bismuth in the future.

By far the largest producer of bismuth is Bolivia, whose exports for 1906 amounted to $722,978. Other countries that are either actual or potential producers of the material are Bohemia, Mexico, New South Wales, Norway, Spain, and Tasmania.

The wholesale price during 1906 was much lower than has often prevailed, ranging around $1.25 per pound. This condition was generally attributed to the desire of the controlling firms to crush out competition, a new refinery having been started in Germany.

Bismuth is used chiefly in pharmaceutical preparations, such as the subnitrate, the combinations with the haloids, and the tennate. It is also used in low-fusing alloys or cliché metal, and to a small extent in glass.

The condition of this industry in 1906 is reported by Frank L. Hess, geologist, of the United States Geological Survey, in an advance chapter from "Mineral Recources of the United States, Calendar Year 1906," which is now ready for distribution by the Survey.

Alumni Association of the Franklin Institute.

On Monday evening, April 27th, 1908, about seventeen graduates of the schools of the Institute assembled in the Hall for the purpose of forming an Alumni Association.

Mr. Walton Clark, President of the Institute, presided, and assured the meeting of his approval of its object and his hearty cooperation and that of the Board of Managers and prophesied an interesting and important future for the Association.

Mr. William H. Thorne, the Director of the Drawing School, spoke of the value of such an association, both to the graduates and to the Institute, and hoped that great care would be exercised at the beginning in the forming of the Constitution and By-Laws and the selection of the officers, in order that permanency and success might be assured.

Mr. George S. Cullen, an old graduate and instructor, discussed eligibility for membership. Enthusiastic approval of the object was shown by the remarks of Messrs. Pedrick, Jones, Parsons, McCaffrey, Delaney, Fisher, Fennell and Davis, and Dr. Wm. H. Wahl, Secretary, and Mr. Henry Howson, Vice-President of the Institute.

On motion of Mr. Delaney, it was unanimously resolved that "It is the sentiment of this meeting that an association of the students of the Franklin Institute be formed and that the graduate students attendant at this meeting constitute themselves the charter members of such association."

On Motion of Mr. Fennell, it was resolved that "A committee on Constitution and By-Laws be appointed by the President of the Institute, to consist of five members, and that Mr. Thorne be appointed chairman."

On motion of Mr. Fennell it was resolved that "A committee of five be appointed by the President of the Institute to nominate permanent officers of the association."

The President appointed the following as the Committee on Constitution and By-Laws: Messrs. Thorne, Parsons, Cullen, Jones and McCaffrey.

On motion adjourned.

WM. H. THORNE, *Secretary.*

A meeting for the purpose of considering the reports of the Committee on Constitution and the Committee to nominate permanent officers was held on the evening of October 12th, 1908, in the Hall of the Institute. Mr. William H. Thorne, Director of the Drawing School, called the meeting to order. In the absence of Mr. Walton Clark, President of the Institute, Mr. Clement Remington was made temporary chairman. The following constitution was considered and discussed section by section and finally adopted:

CONSTITUTION OF THE ALUMNI ASSOCIATION

OF THE

FRANKLIN INSTITUTE.

ARTICLE I.

Name.

SECTION 1. The name of this organization shall be THE ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

ARTICLE II.

Object.

SECTION 1. The object of this Association shall be to promote the interests of the Institute and of its schools and of the alumni.

ARTICLE III.

Membership.

SECTION 1. The Association shall consist of Members, Life Members, and Honorary Members.

SEC. 2. Every graduate of the Franklin Institute schools, by virtue of his or her diploma, may become, upon application to the Membership Committee, a member of this Association, and shall be entitled to all the rights of membership as long as he or she complies with the regulations of the Constitution. Provided, no one shall be entitled to hold office or to vote unless he has paid all dues in full to date. Former pupils of the schools not having received diplomas, may become members upon application, if recommended by the Membership Committee, and elected by a two-thirds vote of the members in attendance at any stated meeting.

SEC. 3. Any member in good standing may become a Life member of the Association by the payment of $20.00 at one time, and shall thereafter be exempt from the annual assessment levied to meet the ordinary expenses of the Association, for which purpose the income only of Life membership money shall be used, the principal to be invested. In all other respects,

the status of the Life member shall be the same as that of the regular members.

Sec. 4. Honorary members may be chosen from among any individuals who have been of great service to the Institute. They must be nominated by a member in good standing and recommended by the Membership Committee and elected by a two-thirds vote of the members in attendance at any stated meeting. An interval of a year shall elapse between the proposal and election of an Honorary member.

Sec. 5. The Membership Committee shall consist of six, two members of which shall be appointed annually for a term of three years by the President, who shall be chairman of such Membership Committee. The first President of the Association shall appoint the first Membership Committee, and two of the six so appointed shall retire by lot at the expiration of each of the two years next succeeding.

ARTICLE IV.

Dues.

Section 1. Each member shall pay on admission a fee of 50 cents, which fee, with the Life Membership fees, shall be put at interest and the income only used.

Sec. 2. Each member shall pay annual dues of $1.00 to the Treasurer on or before the first Monday in May of each year. Any member in arrears for dues for two years shall be notified by the Treasurer, and if such arrears are not paid within thirty days after such notice, then the member so in arrears may, at the option of the Executive Committee be dropped from membership of the Association. The Executive Committee shall have power to restore to membership any former member so dropped from membership, who shall make application for such restoration, and pay to the Treasurer the dues for each year since his last payment.

ARTICLE V.

Officers.

Section 1. The officers shall consist of a President, a First Vice-President and a Second Vice-President, a Secretary, a Treasurer, an Archivist and an Executive Committee, which committee shall consist of the President and Secretary and eight other members elected for a term of four years, two being elected each year, except that eight members shall be elected at the first meeting of the Association and these eight members shall determine their respective terms of office, four, three, two or one year, by lot. All the officers except the Executive Committee shall be elected for a term of one year, and the President shall not be eligible for consecutive re-election.

Sec. 2. The Executive Committee shall appoint at each stated meeting of the Association, a Nominating Committee of seven members, which committee shall present to the next stated October meeting, nominations for the several officers named in the preceding section. The meeting shall thereupon proceed to an election. The election of officers shall be by ballot, and

the officers so elected shall take office upon the adjournment of the meeting at which they are elected.

SEC. 3. Twenty or more members entitled to vote, may constitute themselves a special nominating committee with same powers and limitations as the nominating committee appointed by the Executive Committee.

SEC. 4. It shall be the duty of the President to preside at all meetings of the Association; to preserve order, and to vote in the case of ties only.

SEC. 5. In the absence of the President, the senior Vice-President present shall perform the duties of the President.

SEC. 6. The duties of the Secretary shall be to record the action of meetings; to keep a correct list of all members; to give timely notice of all special and stated meetings; to receive and answer all corrspondence of the Association and to lay the same before the next stated meeting; to preserve correct copies of the minutes, to deliver to the Archivist all addresses, essays, and correspondence, and to notify the new members and officers-elect of their election and members of Committees of their appointment.

SEC. 7. It shall be the duty of the Treasurer to collect all fees; take charge of all funds of the Association; pay all bills approved by the Executive Committee and endorsed by the President, and at each regular meeting to present a written statement of the finances. His accounts shall be audited annually by a committee of three appointed by the President at each May meeting. This committee shall report to the next stated October meeting.

SEC. 8. It shall be the duty of the Archivist to have charge of the archives belonging to the Association. He shall be the custodian of all addresses and essays of members, of all drawings, sketches, paintings, models or productions of the schools and alumni which may be donated, and of all trophies and insignia belonging the the Association. He shall arrange in files all correspondence of the Association, all receipted bills, and such other memoranda as may be deposited with him by the Executive Committee. He shall have charge of the rooms and furniture of the Association and be responsible for the display and care of attractive or valuable archives, subject to the regulations of the Board of Managers of the Institute. He shall reside within twenty miles of the Franklin Institute Building.

SEC. 9. It shall be the duty of the Executive Committee to make the necessary arrangements for the meetings of the Association; to obtain suitable persons to read essays to the Association; to examine each bill presented for payment and to approve or reject the same, to attend to all business not otherwise provided for, and to act when so requested in an advisory capacity to the Directors of the Schools. It shall make a full report of its actions to each stated meeting.

ARTICLE VI.

Meetings.

SECTION 1. There shall be two stated meetings annually, viz.,—on the first Monday in May and on the first Monday in October. Other meetings shall be held as may be provided by the By-Laws.

Sec. 2. Special meetings may be called by the President, and must be called by the President upon the written request of twenty members of the Association.

ARTICLE VII.

Amendments.

Section 1. This Constitution may be added to, or amended, at any regular or special meeting upon a two-thirds vote of the members of the Association present. Provided, the proposed amendment shall have been presented to the Secretary over the signature of not less than twenty members, and a copy mailed by him, together with the notice of the meeting, to each member of the Association, not less than fourteen days prior to such meeting. It shall be the duty of the Secretary to mail each member a copy of any properly proposed amendment as above.

The Nominating Committee presented the following candidates for the various offices and they were unanimously elected:

President, George S. Cullen.
First Vice-President, Percy Stokes.
Second Vice-President, Edward T. Parsons.
Secretary, Thomas G. Jones.
Treasurer, Edward V. McCaffrey.
Archivist, Lucien E. Picolet.

Executive Committee:—
Louis Laherrere.
Howard G. Balz.
Anders Forsstrand.
R. S. Garren.
Frank H. Lobb.
Clarence C. Fithian.
E. Winfield Finkbiner.
Oscar Mowrey.

The following persons have complied with Article 4, Section 1, of the Constitution and thereby become members of the Association.

J. T. Fennell, 311 Walnut St.
John H. Wackenhut, 2104 Montgomery Ave.
Wm. B. Champion, Haddon Heights, N. J.
Thomas J. Delaney, 2463 N. 31st St.
L. Laherrere, 1822 Mt. Vernon St.
R. S. Garren, 1318 Spruce St.
Edw. C. Pladder, 513 Perth St.
J. E. Schultzer, 223 N. 7th St., Chester, Pa.
Frank H. Lobb, 432 Carteret St., Camden, N. J

Theo. H. Glockner, 29 E. Seymour St., Germantown.
Warren M. Stone, 113 Linden St., Camden, N. J.
Edw. F. Parsons, 19 N. 24th St., Camden, N. J.
John McCoy, 57 E. Mermaid Lane.
Jas. R. McCausland, 1831 N. 19th St.
Fred. W. G. Haussman, 328 Brown St.
Thos. J. McLoughry, 2009 Norris St.
Chas. Seifert, 2344 N. 25th St.
George Todd, 532 E. Cabot St.
Chas. F. Huegle, 1239 N. 5th St.
Valentine J. Huegle, 1239 N. 5th St.
Alvin B. Hatfield, 2612 Glenwood Ave.
E. Fisher, 926 N. 4th St.
Gomer Hogstrom, P. O. Box 201, Riverside, N. J.
Anders Forsstrand, 2104 Ontario St.
Alex. Arnois, 1304 Arrott St., Frankford.
W. A. McCaffrey, 1711 N. 4th St.
John F. Abbott, 5107 Hazel Ave.
Oscar Mowrey, 1647 Newkirk St.
Malcolm Lovett, 5022 Market St.
Clarence C. Fithian, 1109 Wallace St.
Louise Fithian, 1109 Wallace St.
Herman J. Ruch, 172 Woodland Ave., Woodbury, N. J.
E. W. Finkbiner, 5218 Stiles St.
Jas. C. Wobensmith, 1011 Chestnut St.
Harry Harres, 1017 Lombard St.
Percy Stokes, 1822 N. 16th St.
Thos. G. Jones, 2063 E. York St.
Geo. S. Cullen, 4504 Springfield Ave.
E. V. McCaffrey, 1711 N. 4th St. (Life Member.)

THOMAS G. JONES, *Secretary.*

Book Notices.

Steam., Its Profitable Utilization. By Geo. H. Gibson. 12 pages 6¾x10 in., illustrated. Reprinted from The Book-keeper by the Harrison Safety Boiler Works, Philadelphia, Pa. For gratis distribution to managers and others who are responsible for the economical performance of steam plants.

While presumably written with a view to exploiting the products of the above named firm, this pamphet describes in considerable detail the requirements of various prime movers, tracing out the distribution of heat in the various parts of the system and pointing out when economies may be effected and the means by which they may be carried out.

One conclusion reached is the greater economy resulting from a utilization of exhaust steam than from the installation of elaborate power producing apparatus of high efficiency. P.

Erratum.

Vol. CLXVI, No. 5, November, 1908, pp. 390 and 392.

Page 390, last three lines read:

"At Queen Lane, the system will have each of the five features mentioned above, the water flowing, by gravity, from the sedimentation reservoir (the south basin of the"

Page 392, Queen Lane filter plant, omit "Low lift pumps over N. basin."

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLXVI, No. 6 83RD YEAR DECEMBER, 1908

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Mechanical and Engineering Section.

(Stated meeting held Thursday, November 19, 1908.)

Natural and Artificial Conservation of Water Power For Electrical Purposes.

BY EDWARD R. TAYLOR.

The call of the Governors' Conference by President Roosevelt last May was the inauguration of a development of resources more stupendous than ever before contemplated by any people upon the face of the earth, and it is destined to be of value to our people beyond any present power of computation. Startling facts were arrayed showing the rapid and near-by exhaustion of resources which when once used can never be replaced, and emphasis was placed upon the necessity of utilizing other resources now going to waste which might delay the exhaustion of the unreplacable.

Of all our resources capable of meeting these exigencies, no other begins to compare with the systematic and perfect development of our water power, and no other so abundantly helps navi-

gation and commerce without which the marketing of our products, manufactured and otherwise, cannot adequately be performed. Our railroads have admitted their inability to do the work required of them, and even the expenditure of hundreds of millions of dollars would not make them capable of doing what in the nearby future would be required of them, if unaided by water navigation.

I deem myself happy therefore to have been invited by the Franklin Institute to address you to-night on the "Natural and Artificial Conservation of Water Power for Electrical Purposes." These last two words are important, for electricity has made possible the development of water power in one place and its utilization in another, a fact so familiar that I do not need to dwell upon it at this time.

In the conservation of water for power purposes, forests are of great value. They prevent the wearing away of soil so essential to all vegetable growth and by the decay of the fallen leaves add to fertility, and make possible the absorption and retention for a long time the water that would otherwise run quickly away. They also retard the melting of snow in the Spring and thus conserve water for later use. But while the ground is frozen it cannot absorb any more water and unless there are lakes, ponds or reservoirs to receive this water it passes rapidly to the sea, carrying many times devastation in its way, so much so that the annual damage by floods in the United States alone is computed at not less than $100,000,000.

Forestry alone is incapable of meeting the exigency and must be supported by water storage to be really effective. This water storage should begin in the farmers' brook.

Mr. W. A. Ritter wrote a fine description of Mr. Chas. Call's power plant, published in the Ohio Farmer of July 25th, 1908.

This picture of Mr. Chas. Call's dam, which impounds the water of a brook which you can easily step across, is an illustration of such a development. Two months from the time Mr. George H. Lodge, of Cuyahoga Falls, his son-in-law, started with him to build that dam, they were lighting Mr. Call's house and other buildings by electricity produced by that babbling brook. It is simply an earth dam with a concrete spillway with some stones the farm could well spare for the water to fall upon.

A little brook, yet that great passage way thirty-two feet long

and say two feet high was filled within five inches of its top last Spring, and when I visited his home a few weeks ago, I found Mr. Call had added eighteen inches to the height of his spillway and was scraping the earth in to increase the height of the rest of the dam. He said it was surprising how fast they could fill the dam up in that way. In such work the earth should always be higher than the concrete and the concrete high enough so that the water can never get over its sides, no matter how heavy the flow of water coming down. With these precautions earth dams

Dam of Mr. Charles Call. From "Ohio Farmer."

when properly constructed, especially if they have a diaphragm of concrete deep down and running their whole length and planted with willows are in many places the cheapest and best dams. This dam is over 300 feet long and cost about $400 to construct. The total equipment about $1200. A $60 chandalier shows its elaborateness. When the dam is filled with water it covers about four acres and affords pleasure for boating, swimming and fishing. Under the dam at this point is a sewer pipe eighteen inches in diameter connecting with a rectangular box open at the top and at one side and passing to the lower side of the dam. By lifting

the gates on the front part of this box the pond was emptied of its water to do the work shown and a large quantity of fish revealed. As a matter of fact such a pond properly stocked with fish is capable of yielding more value per acre than the ordinary farm will produce by cultivation.

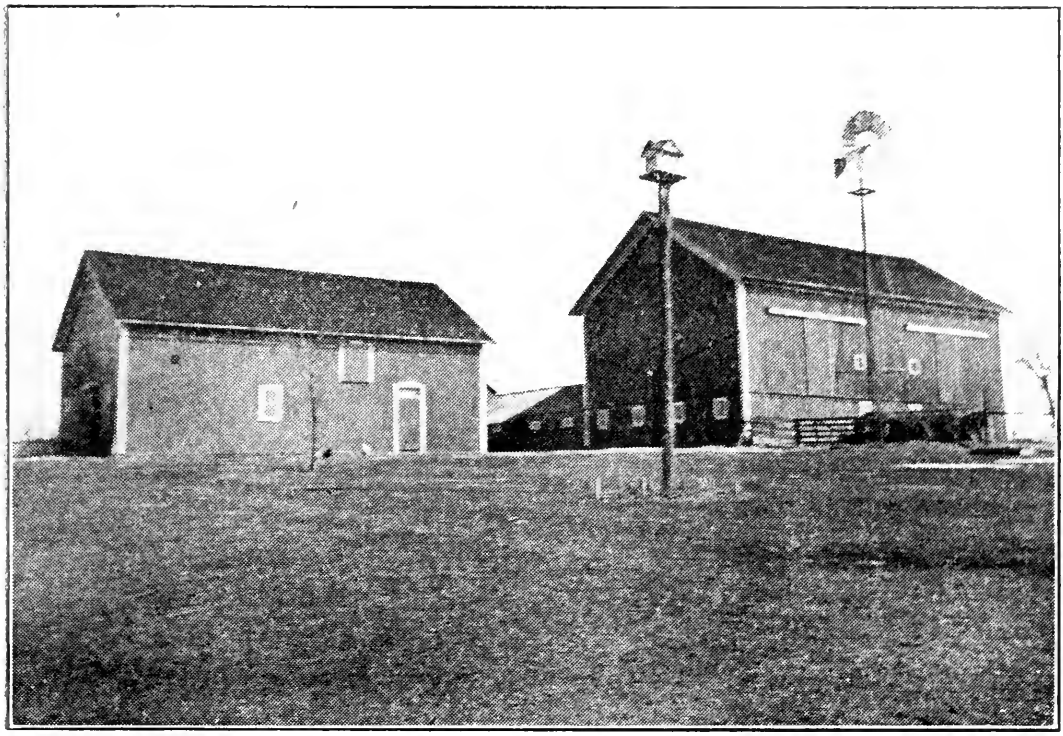
The power house is shown at the left, in which is a six-horse-power water wheel and five kilowatt dynamo. This furnishes light and runs some small machines. The wheel is started and stopped by a wire running to the house and attached by very in-

House of Mr. Charles Call. From "Ohio Farmer."

genious contrivance to the gate of the water wheel. Mr. Lodge deserves great credit for the ingenuity shown in the installation of this plant. The discharge pipe for overflow and for emptying the pond is shown in this picture, and in front of it in the willows is shown the little brook hardly more than two feet across at that point. Mr. Call says there are seven or eight places on that little stream where other farmers can do as well or better.

It was nice to note the generous credit Mr. Call gave the young men, Messrs. Lodge and Ritter, for the accomplishment of this work, and right here I may say, I believe there is a large field for

competent young men to assist farmers in such developments. There are literally thousands of such opportunities all through the land, and farmers should embrace them without delay. It will mean the aggregate storing of immense quantities of flood waters in the feeders of large streams and enhance the value of such farms from 25% to 50%, to say nothing of the luxury of electric lights and electricity applied to plowing, seeding, reaping, mowing, haying, cultivating and other outside operations, per-



Barns of Mr. Charles Call. From "Ohio Farmer."

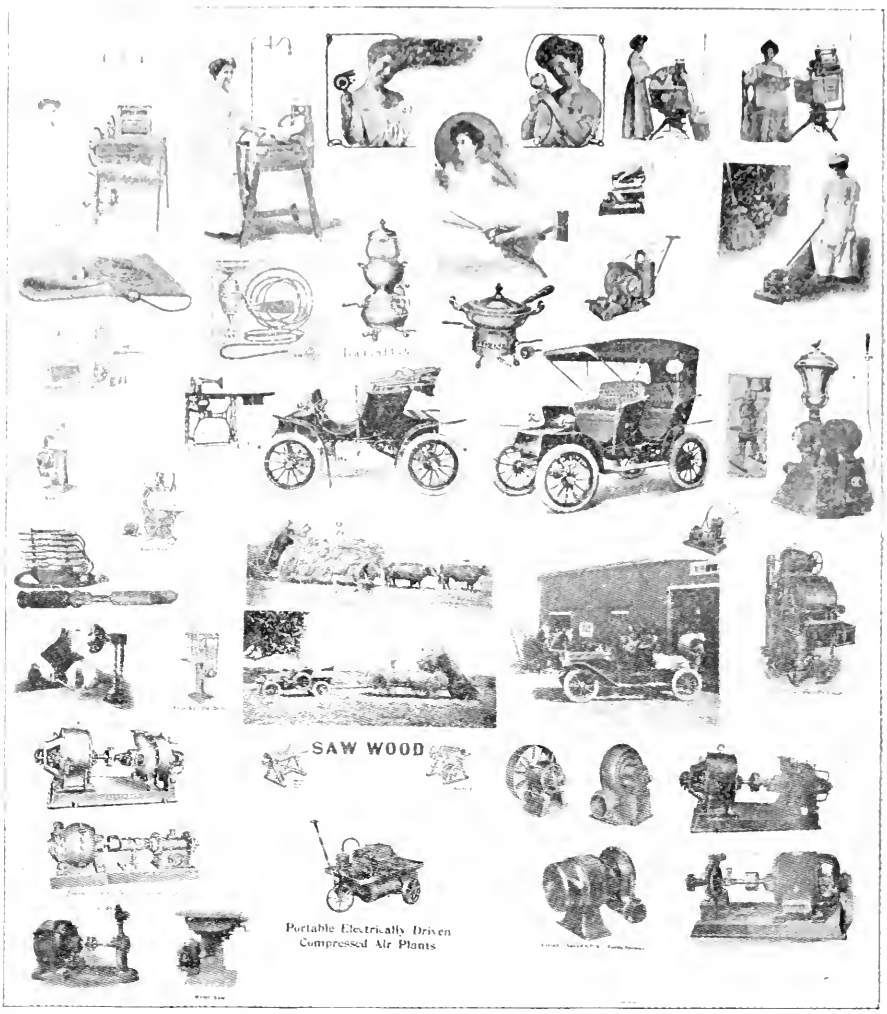
formed with the aid of the electric automobile applied to farm uses.

A starter is shown in the haying scene exhibited, and in the same house, washing, ironing, cooking and a multitude of little things where heat is required, as also in many cases heating the house in winter time.

Mr. John T. McDonald, of Delhi, N. Y., has another similar and larger development, being about twenty-five horse power, and in addition to lighting his house and barns he has a shop with saws, planers and special machinery, and finds it very handy on rainy days to spend them in comfort and pleasure with his men in

doing useful work by machinery. This is finely described by Prof. H. L. Bailey, in the Outlook for August 25th, 1906.*

He has a model farm in the upper Delaware Valley, says he can develop as much again power as he has now, cuts ice from his



pond for himself and neighbors (as does Mr. Call previously referred to). There are other such developments in the country to which I need not now refer.

---

*On returning I visited the farm of Mr. McDonald. There were once eighty-nine saw mills on that little brook, and his is now the only water power development on the stream. It is about 1400 feet above sea level, and the whole upper country of the Delaware and Susquehanna present the most abundant possibilities of lake storage. See map of Banff country, which illustrates it very well, though it is more mountainous than the Delaware country.

These are small beginnings, but they are the forecasts of lots of others, all of which means the conservation of water and the equalization of summer flow.

Nowhere can a like expenditure of money count so much for the comfort and betterment of home life on the farm, and power conditions lower down on the stream.

In early times even small water powers determined the location of places. For years Cleveland, Ohio, was a hamlet near Newburg, the start of the latter being determined by a small water power that is now abandoned.

In many cases ideal sites for power were inadequately developed by the first users, who had power enough for their purposes, and did not, or could not, purchase sufficient land to compass the solution of an ideal site.

At Kent, Ohio, is shown a dam constructed on ideal plans and in an ideal situation, with rock bottom and sides, originally constructed by the State for canal purposes, its use for power being secondary, and no advantage was taken of the opportunity to buy cheap land above for storage purposes. Now the land would cost a great deal, besides a railroad has possession of one of its banks. A beautiful piece of stone channel cutting is shown in making place for the railroad. But for this condition and the high price of land above, this would be an admirable site for larger development and storage of water. The gorge is shown above the dam with its regular sides.

This location is famous for the historic leap of Captain Brady, who in fleeing from the Indians jumped the chasm as they were almost upon him. It was an almost superhuman thing to do, but he was successful and succeeding in hiding himself among logs and lily pads of Brady Lake, while the Indians had to pass around to a ford higher up the stream. Though walking over his head upon the logs they failed to find him.

Cuyahoga Falls also illustrates another inadequate early development of an admirable site. At a suitable time overflow land could have been purchased at a moderate price and a large storage secured between Kent and Cuyahoga Falls. As it was the fall was great and gave them all, and more than all, the power they required.

The next picture shows the three upper dams in succession and the arrangement of flumes and buildings is a fair illustration of

marred natural beauty that make us rejoice that more artistic and beautiful developments are being made to-day. Other parts of the gorge below are very beautiful.

Some years ago a race was started in the gorge to convey water to Akron, about four miles below, where there is a fine head and large water power development. The Salt River Power Canal illustrates the modern construction of such a power canal and shows the great value of concrete construction for such work. In all these there was no conservation of water in any proper sense, and is a fair illustration of the irregularity of river flow without storage reservoirs, and the Cuyahoga is like the majority of streams throughout the country, almost dry at times and surging bank full at other times, when it goes down in such quantity that it can be turned to no useful account, and often carries destruction in its way.

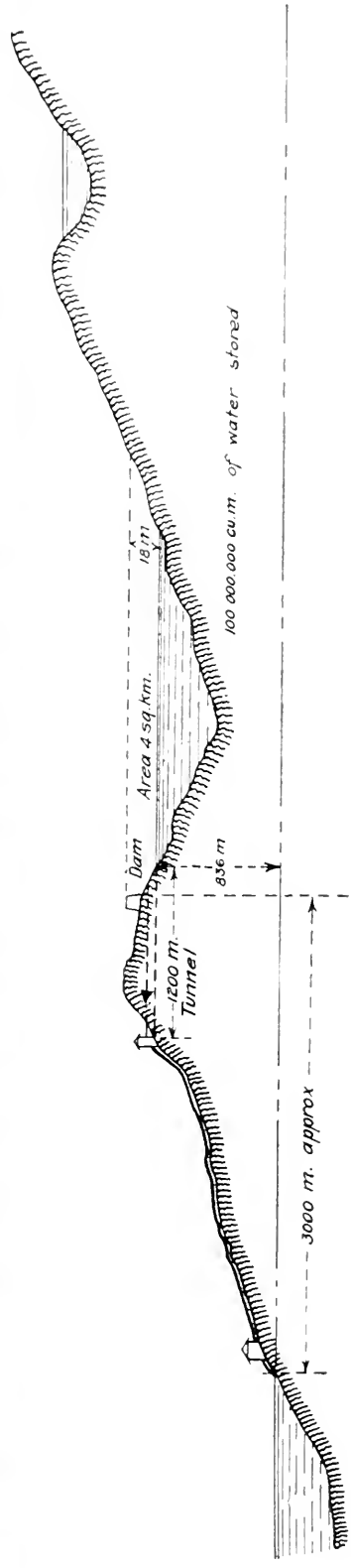
Look at the map of the United States showing the rivers. The lake regions of New York and New England, to a certain extent, conserve water and make more or less valuable water powers, but are by no means adequate and should be both enlarged and increased in numbers to do what is required of them. On the other hand such streams as the Delaware and the Susquehanna are threads of water without lakes, very low in summer and flooded every year with water that ought to be stored in the hills from whence they came. There is abundant opportunity.

The feeders of the Ohio are largely the same, throwing an aggregate of water into the Ohio, carrying damage and destruction all along their course. This can be saved by reservoirs in the Appalachians.

There is probably not a single year when the flood damage to Pittsburgh does not exceed $3,500,000, while in the summer boats are loaded with coal and held in the upper waters to be floated at flood down the river. How much better to reforest the hills and impound the water in the ravines and make the Ohio and many of its branches navigable the whole year through, at the same time saving from inundation millions of acres of immensely valuable lowlands of the Mississippi Valley, while lands very much less in value are used in the up-country to store this water, at the same time developing power that is valuable.

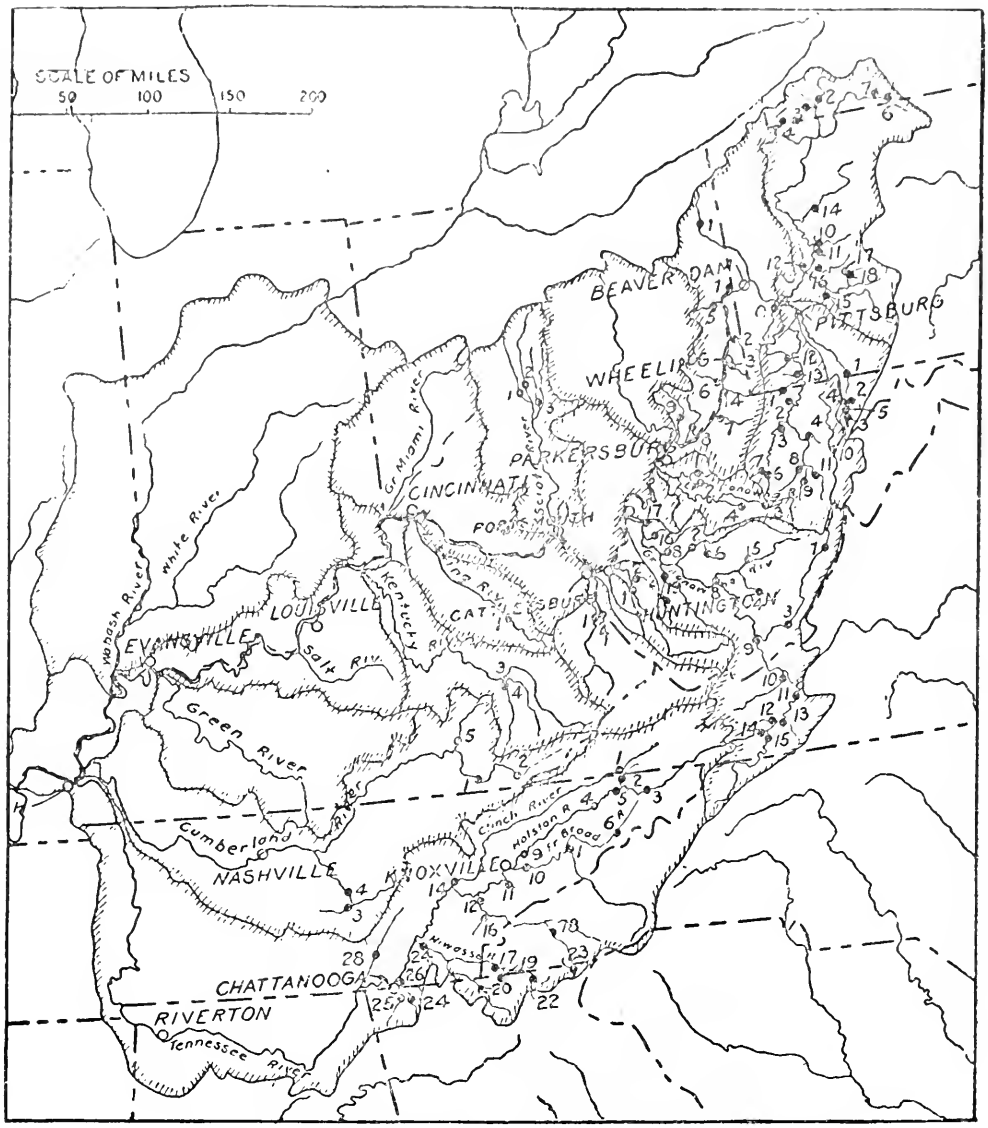
The place to hold water back is in the upper parts of the country where land is cheap. A hundred million dollars damage by

Ideal country in which to build dams, make large lakes and store water.



Ideal water power site in Norway. From "Electrochemical Industry."

flood every year is a high price to pay for our folly. Better pay a portion of that amount per year in making storage for water and reforesting suitable places and develop water power which, in addition to paying for the cost, will save millions of dollars per



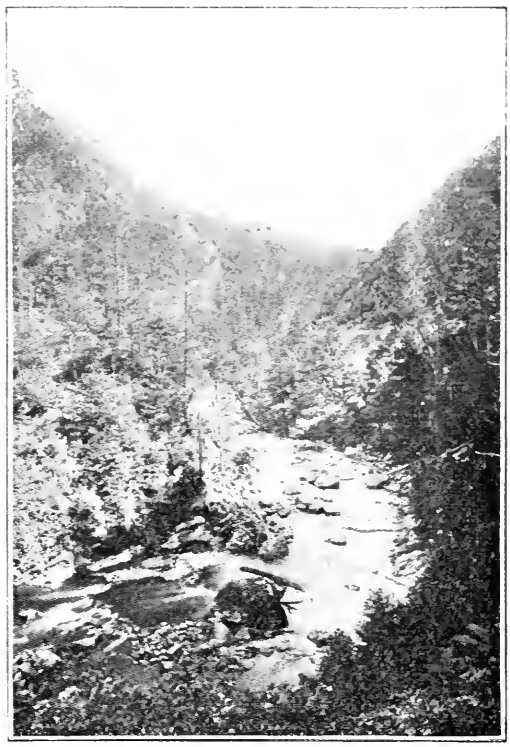
Proposed water storage in the Appalachians. From "World's Work."

year in coal. Banff illustrates an ideal country for water storage.

Dr. Putnam, before the Governors' Conference, made clear that 30,000,000 horse power of water can comparatively cheaply be developed in the United States, while the development of 150,000,000 horse power could be practicably considered. When one reflects

that the useful application of one horse power of water per year is the equivalent to saving twelve tons of coal per year, we may well ponder as to the proper utilization of the immense power at our disposal.

As a rule land that is not very valuable may be used for storage purposes, and even if it is valuable, in some cases, would be more valuable for use in impounding water than the uses to which it is now put. Ravines abound and are better so used than not. The dam can be in many cases largely made of stones that



Doe River, Tenn. Ravines for storage and power.
From "Forestry and Irrigation."

now cumber the ground and the farms be the better for their removal.

The Oswego water shed is advantageously situated for such installations and there are literally thousands of farms where this water storage and power can be installed and with it may come the annual saving of thousands of tons of coal, at the same time relieving the finger lakes of much of the strain put upon them in the rainy season.

Many examples of such possibilities could be given, such as

Big Stream, which has its rise in Tyrone, in Schuyler County, at an altitude of about 1100 feet, passing through Yates County into Seneca Lake, through a good farming country, and having a fall of more than six hundred feet in the course of ten or twelve miles. Such a stream as this properly harnessed is capable of doing the ploughing, seeding and harvesting of the farms through which it passes.

Flint Creek, in Yates County, also offers possibilities more pretentious, and has in addition considerable lake storage possibilities that should certainly be investigated. There are several small dams already on this creek, that can without doubt be enlarged and turned to more useful account by means of dynamos.

Kashong Creek passes through a gulley above Bellona, where a large storage pond could be made and a fall of sixty to eighty feet obtained at Bellona, which could be developed to the great advantage of the town, where a twenty-foot head is now developed and runs a grist mill. These are simply spoken of as examples. There are hundreds of similar cases.

There are other respects in which this water shed is unique, in that there are multitudes of deep glens offering heads of from 100 to 300 or 400 feet, and above them gulleys of small value which could be dammed and large quantities of water stored.

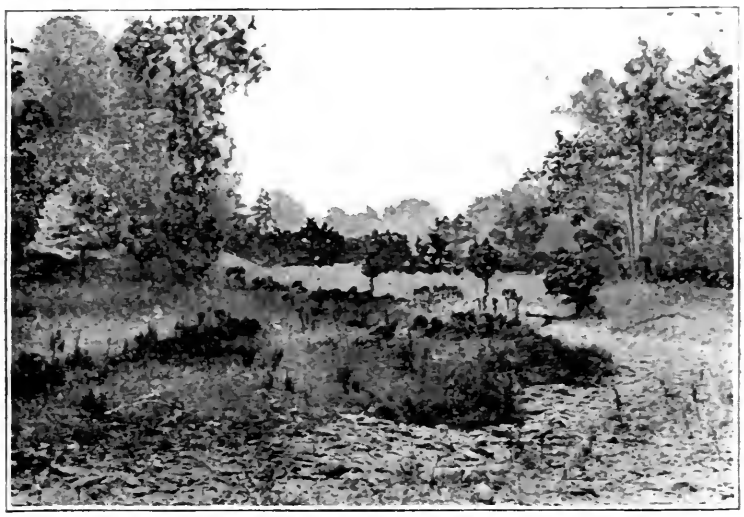
One of the most noted of these is Watkins Glen. I speak of this with delicacy. Some people would say, "Would you blemish Watkins Glen with a water power?" I say, no, I would beautify it with a water power. The storage would be all above the Glen where people visit, and enough water could be allowed to pass in the summer over the cascades to be more than equal to the low water of summer, as it is now. There is very large room for ponds, and even lakes, in the upper part of this stream where very large quantities of water could be stored, and the power used at Watkins to very great advantage.

There is a similar Glen at Hammondsport. A power development in a similar glen at Ithaca was made several years ago and has been in successful operation ever since. The secret of making all of these glens successful producers of power is to secure abundant bondage at higher levels. This is probably possible in every one of them in every case with a rock bottom for the foundation of suitable dams.

Little Lake and Lamoke Lake, in Schuyler County, are at an

elevation of 387 feet above Lake Keuka, and only about two miles therefrom. Their outlet could be dammed at Bradford and their level raised and made into one lake seven or eight miles long and about one mile wide with a large power development at Keuka.

As the waters from these lakes now makes its way into the



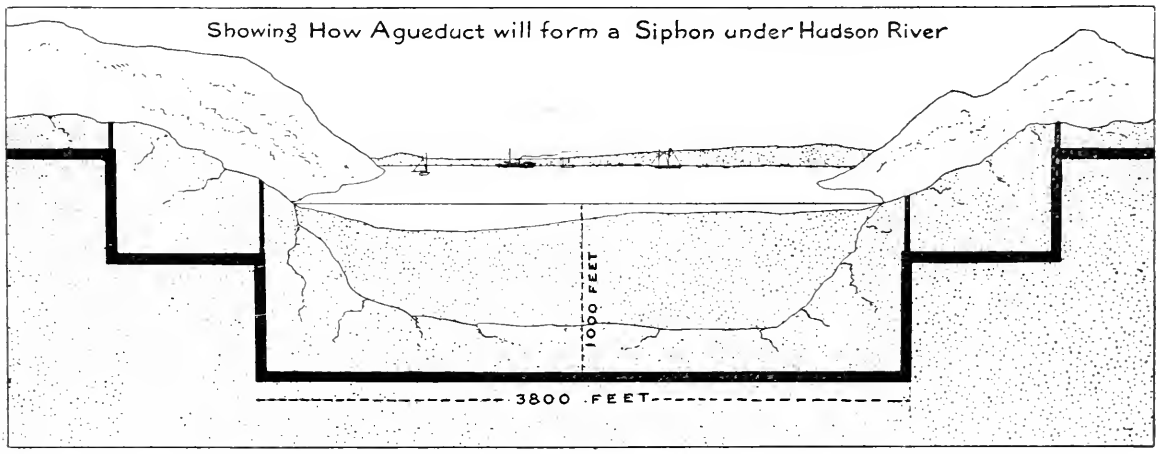
Pondage site above glen.

Site for dam above Glen. Taken n dry weather.

Chemung River, a tributary of the Susquehanna, its diversion to the Oswego water shed would have to be made a matter of Inter-State agreement. This raises a very important question, as there is often great advantage, as in this case, to be derived from diverting water from one water shed to another. Where for similar reasons the water can be used to better advantage. Here is a fall

of nearly 400 feet in the space of two miles with a fair supply of water, means a very large power, as 100 pounds per minute means the continuous development at this head of more than one horse power and savings of twelve tons of coal per year for each horse power.

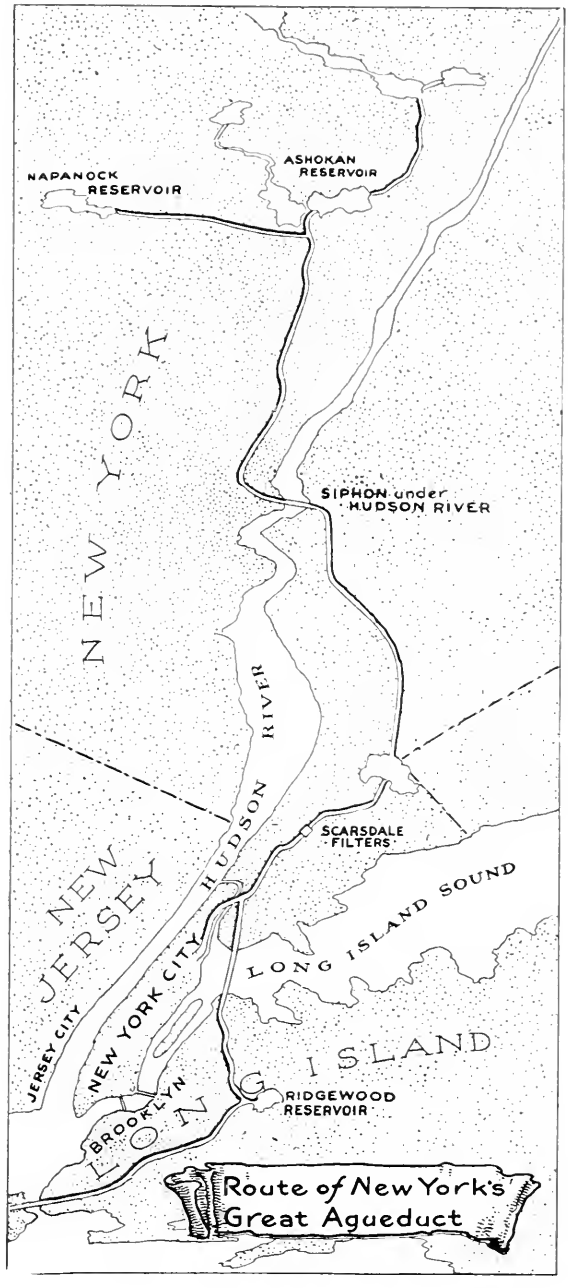
Making concrete aquaduct. New York City Watee Supply.



New York City is about to expend $165,000,000 in storage and conveyance of water from the Catskill Mountains, a distance of eighty-five miles.

This great enterprise includes a great syphon to convey the water under the bed of the Hudson River. There will be a fall

of 610 feet, at least 300 feet of which could be used for power purposes, with the possible development of nearly 35,000 horse power and the saving of 420,000 tons of coal per year. I am indebted to the *Popular Mechanics* for this illustration showing a



map and plan for syphon under the Hudson River and an aqueduct of concrete.

Notwithstanding a fall of more than 100 feet at Rochester, the water is so low in summer in the Genessee that less than

2000 horse power is available, when by proper storage 100,000 horse power would be available the year round at that one point.

It has been proposed to construct a dam at Portage and impound a large quantity of water above the gorge at that point. A map of the proposed lake is made showing the present position of railroad tracks and the position they would occupy when removed to make way for the improvement. This great undertaking is advocated by the New York State Water Supply Commission, and I am indebted to them for the map above referred to. They are also proposing to make a similar storage on the Sacandaga River, north of Albany, in the State of New York.

Four great storage reservoirs and one hundred and thirty-five feet fall of water utilized makes Niagara Falls the seat of power that it is to-day.

The Genessee River might offer the next best power in the State, but it has no important lakes and more than one hundred times as much water passes in flood as at its minimum flow.

Not so with the Oswego River, only about twenty-five times as much water goes through it at flood as at minimum flow.

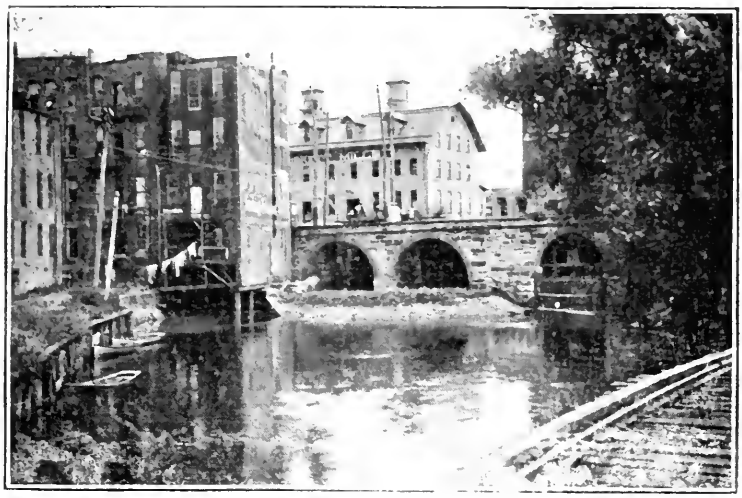
The storage capacity in what are known as the Finger Lakes of our State make the difference. These are natural reservoirs in a very small measure assisted by dams to retain much of the flood water, with the result that it is probably the more regular water power stream that has its rise in the State; yet under present circumstances it is more than usually pressing that we should ask if the present water storage capacity can be materially increased.

The raising of the dam of Canandaigua Lake would probably be attended with the least trouble and damage. The variation in Canandaigua Lake from highest to lowest water, as I understood, does not exceed five feet, and the spring run-off is always very heavy, and the summer very light.

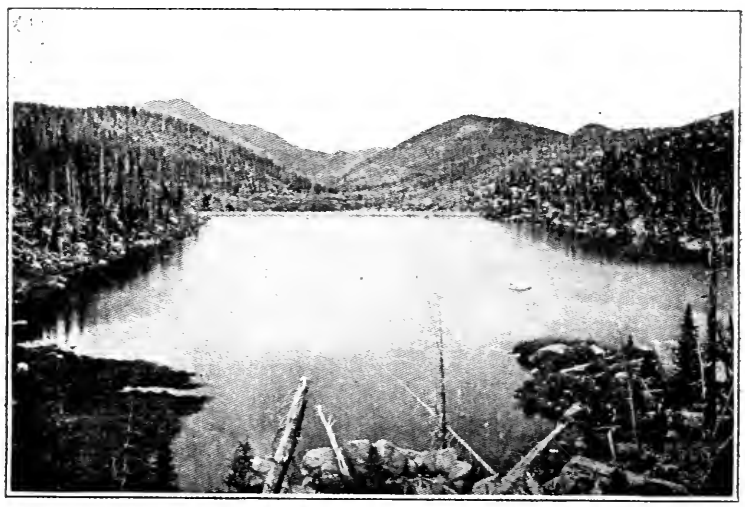
The dam at Keuka Lake makes the possible difference of level of from six to eight feet from high to low, and there are sometimes as much as two or three feet of water goes to waste over this dam. To raise this dam a few feet and secure a larger supply of flood water, would be attended with some damage, but could be provided for by filling low places and other easements at Hammondsport, Branchport, Penn Yan, and some small places, including cottage sites. But this difficulty is not insurmountable. The dam at the foot of Seneca Lake, I understand, is in bad con-

dition and needs suitable repair to enable Seneca Lake to become the storage reservoir that it is capable of being.

Cayuga Lake is the most difficult to deal with of all the lakes of this system, as it is the lowest of them all. But on the other hand, on account of these very features, it could be made the most



State dam, Keuka Lake. Water low.
This controls the water flow.



Burnt over district, Lake suitable for storage. Level should be raised.
From "Forestry and Irrigation."

valuable of all these lakes for storage purposes, as it constitutes the bottom receptacle of nearly all of them.

This leads us to the question that has greatly troubled our ablest engineers, and I only dare to tread on this ground after them because of its transcendent importance.

I have no doubt but because of this sag the engineers have felt the necessity upon them to step the canal now building down in the vicinity of Newark and up again as it approaches the Rome level. This makes necessary the absorption of a portion of the water of the Oswego water shed for the locking of the canal at this lower level.

The level of the proposed Barge Canal, as it leaves Lake Erie, is 564 feet, and it locks down all the way from there to a point a little east of Rochester. Could the level of the canal from this point be maintained to get over the Rome level, which is 391 feet and 6 inches, the problem of a lock down canal all the way from Lake Erie to the Hudson could be solved.

I do not presume for a moment that all of these questions have not been carefully considered by those in charge of the canal work. But we are now up against conditions that have never before made possible the consideration of things in the large way that is absolutely forced upon us to-day.

The West is calling for the cheapest kind of transportation for its grain and other bulk goods to the Atlantic Ocean. The breaking of bulk where it can possibly be avoided is recognized as a very great disadvantage. A canal for navigation purposes alone only fulfills a part of its possible mission, especially a canal that could be made a lock down canal with the total fall of 564 feet to tide water.

If a ship canal coupled with a water power canal were made between Lake Erie and the Hudson River, the value of the water power alone would be a very large factor in paying for its enormous cost. It is to be borne in mind in considering such a great proposition, that when once done, as it ought to be done, it will be a continuous source of large income. We are therefore justified in putting the best thought we can conceive upon this important subject and ask ourselves, Is it worth while? Every ton of water per minute that could be made to pass through water wheels in such a canal to the Hudson River would mean the generation continuously of thirty horse power and the saving of 360 tons of coal per year.

A large development of water power could be made in the vicinity of Lockport, Rochester, Waterloo, Seneca Falls, and from Little Falls to the Hudson River, an enormous development of water power, there being some three hundred feet fall between

these points. We might be justified in such a work for the accomplishment of a great purpose.

Chicago, years ago, found itself in the mud and they assembled as one man and raised those great blocks of buildings and streets, and we have a new Chicago. These were necessities and were done because people had to do them.

The question arises, Is the construction of a ship and power canal from Lake Erie to the Hudson River of sufficient importance to justify the employment of modern means to raise Ithaca and Watkins to a higher and healthier level, and some of the very small places that might be in the way of such a development. These things accomplished the daming of Cayuga Lake opposite Cayuga would make a large storage reservoir of Cayuga Lake

A river on a rampage because it has no storage lakes.
A fair sample of nearly all the rivers in our country.

and enable the level of the canal to be such as to pass the Rome level. A dam across the foot of Cayuga Lake that should have a large spillway and empty the flood water of the watershed into Cayuga Lake would make a large power development possible at Cayuga and equalize the flow of the Oswego River, and thus conserve the flood water of this great and important watershed, and make available the same for the purposes of power and lockage of vessels.

The present Barge Canal is constructed only as a navigation canal, without reference to water power in this electrical age even for the towage of its own boats, and which can be used for that purpose only seven or eight months per year, while the power of a

ship and power canal could be used the whole year through with the production of values running into the hundreds of millions of dollars. It seems passing strange that so important a work should have been undertaken without the cöordination of other interests quite as important as those of navigation. All of these interests should work in harmony for the highest possible development of all of our resources as a people.

From the Report to the Governor of the Advisory Board of Consulting Engineers from January 1st, 1907, to January 1st, 1908, page 21, paragraph 4, we take as follows:

"The Board did not feel justified in recommending a generating or transmission system which would allow of possible expansion of power uses for electric haulage or for the sale of surplus power by the State, holding that this was a matter not connected with the appropriation for the construction of water ways."

"The details of power generation for and application to lock mechanism is being given particular study and a set of tentative designs have been submitted to the State Engineers' Department for consideration."

It will be said by many that all this is out of the question. Galveston and Chicago are to-day greater cities than they could have been but for the great work that they have done.

Ithaca can, by modern hydraulic methods, be raised to a proper position, and concrete docks and breakwaters constructed, before which not only the pleasure steamers of Cayuga Lake shall land, but also the commerce of the world. We should not damage Ithaca, but better it beyond its most hopeful thought of the future. We should not damage the water power users of the Oswego watershed, but bless them with reliability of power such as they have never before known, and not have damage suits from them but money instead, for benefits received.

"Albany, Nov. 16.—Fulton Power Company Has Title to Bed of River, Court of Claims Holds in Big Barge Canal Action. State Loses First Phase of Suit for $3,428,028; May Multiply Canal's Cost Enormously. No Appeal Possible Until Award Fixing Damages has been Reached."

"The State Court of Claims to-day decided against the State in a motion to dismiss the claim of the Fulton Light, Heat and Power Company, of Fulton, Oswego County, for $3,428,028 for

the permanent appropriation for barge-canal purposes of land in Fulton and of the developed and undeveloped water power in the Oswego River there, together with an alleged depreciation in value of the electric light plant of the company."

The claim, which involves a test case on behalf of power concerns at various points whose water power is to be taken over for canal purposes, was before the court on the issue of the State's ownership of title to the bed of the river and the water rights which the companies are seeking to protect, and the claim has not been tried on the question of the amount of damages sustained by the concern. The decision of the Court of Claims undoubtedly later on will be carried to the Court of Appeals.

In refusing to dismiss the claim, the court holds, in an opinion written by Judge Rodenbeck, in which the other judges concur, that the claimant is the owner of the lands which are to be taken for barge canal purposes, which include the power site of the company at Fulton.

The court agrees with various contentions of law advanced for the claimant, but, under the opinion handed down, has reached no conclusion as to the extent of the riparian rights attaching to the land, which must be determined when the trial is resumed.

Until the case is fully closed, and an award fixing the amount of damages is reached, the State cannot review this determination of the Court of Claims in the higher courts.

The main points covered by the opinion are that a State patent bounded by a fresh water non-tidal stream carries title to the center of the stream; and that a private individual may acquire title by prescription in the bed of such a stream, even though the stream may be navigable.

The far-reaching effect of this decision, if it is sustained, in increasing the cost of the barge canal or other improvements to navigation in this State, cannot be overestimated.

There are a score of other sites like Fulton, at each of which there are a score or more of water power users who will file similar claims in like big amounts. It is understood that these water power users are acting somewhat in concert in furthering the prosecution of the claim now on trial.

Trial of the claim has brought out a notable array of attorneys in behalf of the power companies, headed by Prof. C. A. Collins,

former counsel to Governor Flower. The State was represented by Deputy Attorney-General George P. Decker."

We should make a State canal that should lock all the way down from Lake Erie to the Hudson and that should not be simply a navigation canal but a power canal as well, with its large power at several places already referred to along its course where the grains of the great West could be made into flour and numerous industries dependent upon bulk materials manufactured into goods of higher value, so that even the railroads would rejoice in elevating their tracks and running them alongside this great waterway as they see in prospect the millions of cars of high-class, well-paying freight that they shall be called upon to move from the manufacturers along its banks. Dockage in New York City would be relieved by docks wherever needed along such a canal.

This is not a time for war, but for the cöordination of all the forces of the State, and the United States, for the production of a highway to the sea that shall not only carry the commerce of the world, but by its power, convert untold millions of property from a lower to a higher value.

The great State of New York must get out of a thimble and do things worthy of its name, the great "Empire State." But, as a matter of fact, the State of New York need not do this great work alone. The great West, with Chicago as its spokesman, and even financiering, will help in this work as only such people know how to do. Maybe Chicago business men would take the raising of Ithaca as their own responsibility.

Do these great things now, and when the coal mines of Pennsylvania are exhausted, and even long before, our successors shall rise up and call us blessed.

I do not belittle this great undertaking, but the large interests involved are so stupendous that it is necessary to do things wise enough and great enough to cöordinate the whole.

In closing this address, I cannot do better than quote from an address by Mr. McClintock, an eminent engineer, and one of the Canal Commissioners, before business men of Rochester when it seemed certain that a barge instead of a ship and power canal would be built, and also a letter recently received by me from Mr. Lyman E. Cooley, one of Chicago's most eminent engineers, in connection with the drainage canal.

PART OF ADDRESS OF MR. M'CLINTOCK, CANAL COMMISSIONER.

"We demand that the plan adopted shall be one that will give the greatest benefit to the largest number of people. We have studied the surveys made for a ship canal by the way of Lake Ontario, and the various surveys for a barge canal; also the topographical survey of this portion of the State covering the canal which is now complete; also the history of the present canal, and we assert the force of the following propositions:

"1. A barge canal by the way of Lake Ontario would be more for the benefit of Canadian interests than New York.

"2. A barge canal through Rochester and Syracuse would be of no appreciable benefit to any interests in the State except a comparatively small contingent in Buffalo and New York.

"3. It is more than probable that as soon as this State is committed to the construction of a barge canal for 1000 ton barges, work will be begun upon a ship canal from Georgian Bay to Montreal which will give passageway for 8000 ton ships, and such a canal will be finished by the time of the completion of the barge canal.

"4. A ship canal 30 feet deep and 300 feet wide, taking a supply of water from Lake Erie and forming a great navigable river for 350 miles from that lake to the Hudson River is the only scheme that is worthy of consideration by this great State at this stage of its industrial development. Such a canal would be beyond the competition of railroads in the movement of freight. The commerce on it could not be controlled by any combination of ocean steamships or inland railroads, and it can be built so as to make possible the creation of permanent water power worth $500,000,000, distributed at various points clear across the State.

"Such a canal could be built without increasing the burden of taxation, and be made to pay its cost directly.

"We insist that before the people of this State are asked to vote upon the proposition to spend $75,000,000 to $100,000,000 on a barge canal, detailed studies and reports be made upon this project."

21 Quincy St., Chicago, Nov. 2, 1908.

Mr. Edward R. Taylor, Penn Yan, N. Y.

DEAR SIR:—I have yours of the 27th ult. inclosing copy of

your paper read before the Electrochemical Society, which I have read with pleasure. You are thinking along the right lines.

Mr. Geo. W. Rafter did much work in your State on this subject and made some valuable reports.

The project of carrying a supply of water from Lake Erie to the Hudson River was an original idea of Governeur Morris, and has been discussed with every change in the canal. The report of the International Commission, of which I was a member, Washington, 1897, submitted profiles of both the Mohawk and Champlain routes, and suggested the cutting out of the Rome summit to the level of Oneida Lake, and the Fort Edward summit to the level of Lake Champlain. These propositions were estimated by the Board of Engineers on Deep Waterways. See their report, 1901.

The West is in favor of the betterment of all water routes to the sea, but the majority of people look upon the barge canal as an improved toll gate for the special benefit of New York State. The West would not assist in asking the General Government for money for the barge canal, but would be very glad to help in securing the additional money which would be required above the cost of the barge canal to make a first-class ship canal. We want thirty feet and not twenty feet when we get ready to break through to the Atlantic.

We shall have a ship route to the Atlantic sooner or later, and so far as the West is concerned, it will go along the line of least resistance, for an outlet to the sea, in our minds, takes supremacy over any question of route.

Yours truly, LYMAN E. COOLEY.

Referring to Mr. Cooley and the drainage canal: The State of Illinois is about to extend this canal sixty miles, to be a part of "From the Lakes to the Gulf Ship Canal," and Chicago's interest is now centered therein, and it remains to be seen if our slow east has lost its grand opportunity.

It is interesting to note that the stone excavated in making the drainage canal has been found to be worth millions of dollars for concrete and other work. So it might be with a New York ship and power canal in the interest of good roads. Lots of stone, cheap power for crushing and cheap transportation for their use. May we do this great thing.

History, Manufacture and Analysis of Maple Products.

By Albert P. Sy, Ph.D.

(*Concluded from vol. clxvi, p. 352.*)

THE LEAD VALUE OF MAPLE PRODUCTS.

In the Hill and Mosher method, the result might be expressed as "acid value in terms of malic acid" of a maple product. Since in some cases it was found quite difficult to get satisfactory results, it was decided to modify it in such a manner as to determine the "lead" part instead of the acid radicals in the lead precipitate. The earliest preliminary experiments with this method gave these results, for "lead value":

Sugars:

Description of sample.	Known to be:	Lead precipitated by 100 grams of sample "Lead value."
Carrier, No. 11866	Pure maple	.331
Ranke	Pure maple	.455
Franklinville	Pure maple	.343
Little Valley	Pure maple	.373
Bryant	Pure maple	.386
Cöoperative, No. 1	Adulterated	.048
Cöoperative, No. 2	Adulterated	.046
Cöoperative, No. 3	Pure maple	.197
Brown sugar (cane)	Cane sugar	.052
Granulated sugar (cane)	Cane sugar	.006
Maple sugar, made in Lab'y	Pure maple	.429
Half cane, half maple	50% maple	.213

Sirups:

Description of sample.	Known to be:	"Lead value."
No. 10202	Pure maple	.225
10204	Adulterated	.048
12130	Adulterated	.061
12221	Pure maple	.208
10188	Adulterated	.083
10201	Adulterated	.033
12679	Adulterated	.060

10203	Adulterated	.044
10306	Pure maple	.320
13305	Pure maple	.190
13306	Adulterated	.005

The results were obtained by diluting 50 c.c. or 50 grams of a sample to about 200 c.c., boiling, adding about 20 c.c. saturated solution of lead acetate (neutral), settle, filter; the lead precipitate was then decomposed with aqua regia, H_2SO_4 added, diluted, alcohol added and the $PbSO_4$ determined as usual; from this the Pb was calculated. No special precautions as to dilution of sample, filtering and washing of precipitate, etc., were taken; yet the results without exception gave enormous differences between pure and adulterated samples. A preliminary note on this method appeared in the Journal of the Franklin Institute, July, 1906, p. 71.* A great deal of experimental work has been done since and the method is now presented in the form which gives very satisfactory results. Instead of subacetate of lead as used in most all other methods for producing a lead precipitate, the neutral lead acetate is used. The advantages of the neutral salt are—

(1) It does not undergo changes as quickly as the sub-salt.

(2) Its composition does not vary; the subacetate varies in composition, according to method of preparation, from Pb (OH) $C_2H_3O_2$ to Pb_3O_2 ($C_2H_3O_2)_2$ and this is probably the main cause of the discrepancies noticed in other methods where the precipitate is weighed or the volume measured.

(3) The neutral salt does not precipitate caramel like the sub-salt.

(4) The neutral acetate is more soluble in water than the subacetates. At 20°C. 100 c.c. water dissolves 50 g. lead acetate, but only 5.5 g. of $(PbO)_2$ $Pb(C_2H_3O_2)_2$, H_2O; the $(PbO)_5$ $Pb(C_2H_3O)_2$, H_2O is almost completely insoluble.†

After considerable experimental work it was found that much better results can be obtained by using the neutral instead of the subacetate of lead.‡ While it is possible to differentiate by this

*Several months after this appeared, Winton published his "Lead number" method (Jour. Am. Chem. Soc., Sept., 1906, p. 1205). He had developed his method independently, and read a description of it at a meeting of the American Chemical Society, June 28, 1906.

†Schmidt, Pharmaceutische Chemie, II, p. 384.

‡The use of natural acetate of lead was first suggested by Blyth (p. 110, "Foods, their Composition and Analysis"); it is also used in the Hill and Mosher method.

method between pure and adulterated products without special precautions as to dilution and washing, it was thought desirable to determine experimentally the best process for this method, so that different analysts could get concordant results on the same samples. The principal part of the lead precipitate being lead malate, this salt was prepared by adding an excess of a 10% solution of neutral lead acetate to a solution of malic acid; the precipitated lead malate was filtered, washed and dried between filter paper and finally in vacuum over H_2SO_4. An excess of the dry salt was put in distilled water and also in a 65% sirup and heated just to boiling, cooled to 20°C., and the lead determined in part of the clear filtrate; this lead was calculated to lead malate, $PbC_4H_4O_5 \cdot 3H_2O$.

SOLUBILITY OF LEAD MALATE, $Pb\ C_4H_4O_5 \cdot 3H_2O$

100 c c at 20°	Dissolved head malate	Equivalent to Pb SO_4	Equivalent to Pb
Water	0.1547	0.1193	0.0814
Sirup (65%)	0.1701	0.1312	0.0895

This is a solubility which cannot be ignored in adding water to a sample for dilution or for dissolving, and also for washing the lead acetate precipitate, and makes it necessary that the same amount be used in each case. In the above experiment on solubility, lead malate was used. To obtain data as to what may be the solubility of lead precipitates from samples of pure maple products, the following determinations were made, using in each case the amount of water indicated for making the original solution of sample, and using in addition 100 c.c. for washing the lead precipitate:

	Water used for solution	Lead precipitated.	Lead value.
Sugar A, 50 grams.	150 c.c.	0.270	0.540
	200	0.254	0.508
	250	0.234	0.468
	300	0.200	0.400
Sugar B. 50 grams.	150	0.385	0.770
	200	0.348	0.696

Besides indicating solubility, these results also show that, since the composition of the lead precipitate is different from different samples, its solubility is also different.

The solubility of lead malate in water, and therefore the lead precipitate in a sample, increases very much for temperature higher than 20°C., according to Partheil and Hübner.* It is necessary therefore to allow the sample to cool to 20°C. (or room temperature) before filtering off the lead precipitate. The washing also must be done with water at about 20°C.

(5) Basic lead acetates precipitate sugar, forming lead sucrates much more readily than the neutral salt. This would introduce an error in all methods, volumetric as well as gravimetric.

Occasionally it is desirable to have an analysis of a sample that has begun to spoil or ferment. In the early part of the work on this method the samples were diluted and precipitated without being first boiled, as was the practice in all the other methods. In some cases it was found that adulterated samples gave high results, producing as much lead precipitate as some pure samples. On the supposition that products of fermentation, especially CO_2, are the cause of this, the samples were boiled before adding the lead acetate; concordant results were obtained after this. The fact that no account is taken of the fermentation products, and that the samples are not boiled, accounts for irregular and unreliable results by other methods where the precipitation is made directly.

Determinations on samples before and after fermentation gave the following results:

	Pb. ppted by 100 c c of sample "Lead value"	Vol. Pb. ppt. New method p. 123	Wt. Pb. ppt. Canadian method	"Lead number" Winton
No. 41. Adulterated				
Sirup, fresh.....	.102	1.7	1.9	
fermented 5 days...	.112	2.2		
fermented 10 days..	.126	3.6	5.7	
No. 37. Adulterated				
Sirup, fresh.....		1.3	1.38	0.26
fermented 14 days..		2.0	1.60	0.44
No. 48. Adulterated			Sirup No. 26	
Sirup, fresh.....	.020		(6.6 / 8.9)	
fermented 7 days...	.035			

*Arch. Pharm., 241, p. 413.

At this rate of increase in values, some of these samples would soon give data corresponding to those of pure products.

The dilution of the sample with 200 c.c. water is necessary on account of the fact that lead malate is soluble in the acetic acid liberated by the reaction of the lead acetate. Experiments showed that a

100 c.c. of	0.2%	solution	acetic	acid	dissolves	0.10 g.	lead	malate.
"	0.4%	"	"	"	"	0.13	"	"
"	0.7%	"	"	"	"	0.18	"	"
"	0.9%	"	"	"	"	0.20	"	"

A maple product with a "lead value" of .200 would leave enough acetic acid in the solution to make it only 0.11%, if 200 c.c. of water are used. While this would not dissolve very much lead malate, yet it shows that it is necessary that the amount of water used should be specified, and should be the same in all cases.

These investigations finally led to adopting the "lead value" method as follows:

To 50 c.c. sirup or 50 g. sugar add 200 c.c. water; heat to boiling, add 20 c.c. neutral lead acetate (10% sol.), cover, and heat again to boiling; let stand until cold. Filter, wash with 100 c.c. water (about 20°C.). Transfer filter and precipitate to 400 c.c. beaker, add 15 c.c. HNO_3 and 10 c.c. HCl, cover and heat on asbestos plate or gauze, or hot plate; when filter is disintegrated, remove from flame, cool slightly and add 10 c.c. H_2SO_4; heat to fumes to expel all HNO_3; if blackening does not clear in a few minutes, add 5 c.c. more of HNO_3 after cooling a little, and continue heating to fumes. Cool, add 50 c.c. water, boil, cool and add 100 c.c. of alcohol; let stand six hours or over night; filter and determine weight of $PbSO_4$, preferably by filtering on tared asbestos Gooch crucible, wash with alcohol and finally with ether, dry, ignite at low red heat for about two minutes. The weight of $PbSO_4$ multiplied by 1.36586 (2×0.68293 factor for $PbSO_4$) gives the weight of *Pb* precipitated by 100 c.c. or 100 grams of sample, or the *"lead value,"* which should not be less than 0.250 for a pure maple product. It is usually over 0.300.

The following *"lead values"* were obtained on samples of sugar known to be pure:

PURE MAPLE SUGARS.

Sample No.	"Lead value."	
1	.580	
2	.384	
3	.762	
4	.468	
5	.470	
6	.376	(min.)
7	.648	
8	1.024	(max.)
9	.708	
10	.498	
Average	.592	

These sugars were, however, quite dry, the average moisture being only 3.58%.

Among a number of commercial samples of sirups bought in the open market there are thirteen sirups giving data for pure products.

Thirteen commercial sirups, pure:

Average	*"lead value"*	.577
Minimum	"	.260
Maximum	"	1.100

The results from eighteen adulterated sirups are as follows:

Eighteen adulterated sirups:

Average	*"lead value"*	.076
Minimum	"	.024
Minimum	"	.165

While there is considerable variation in the results from pure products, due to method of manufacture, yet there is such a great difference between these and adulterated products that there is no chance for a "doubtful" interpretation.

Experience with this method on several hundred samples has given satisfactory results, in no case "doubtful" and in all cases concordant with the results of a complete analysis. The advantages over other methods now in use seem to be—

(1) The use of neutral lead acetate instead of the subacetate.

(2) A reduction of analytical error to a minimum, the gravimetric result being multiplied by only two instead of by forty, as in the case of another method.

(3) The method is gravimetric instead of volumetric (titration and bulk of ppt.).

(4) Account is taken of solubility of the lead precipitate and the amount of water to be used for diluting and washing is specified.

(5) Error due to products of fermentation in old or spoiled samples is avoided by boiling before precipitation.

(6) With the average water content of 10 to 12 % for sugars and 33 to 35% for sirup, the *"lead values"* are in each case on about the same amount of dry substance, 50 grams of sugar and 50 c.c. of sirup (sp. gr. about 1.33) being taken. It is suggested that for uniform results by different analysts and on different samples, the *"lead value"* be calculated to dry substance.

VOLUME OF LEAD ACETATE PRECIPITATE.

This cannot be described as an entirely new test but as a modification of the tests in which the volume of precipitate is determined. The object in working out this test was to devise a method which is not subject to the variations of centrifugal methods, a method which would give concordant results on the same sample and by different analysts. This and the two following methods are so simple in execution that they can be used in the kitchen or generally, where no chemical laboratory is available.

The *"volume of lead precipitate"* is reported in cubic centimeters per 5 c.c. and 5 grams of sirup and sugar respectively. The procedure is as follows:

5 c.c. or 5 grams are placed in a glass stoppered 25 c.c. measuring cylinder, 10 c.c. of water and 2 c.c. of 10% lead subacetate (official) solution added; mix thoroughly and allow to settle twenty hours; at the end of this time read the volume of the settled precipitate. For pure maple products this will be over 3 c.c., and is usually over 5 c.c.

Results by this test on forty-two samples give the following results:

Sample No.	Known to be:	"Vol. Pb. ppt."
1—Sugar	Pure	6.0 c.c.
2—Sugar	Pure	7.3
3—Sugar	Pure	13.6
4—Sugar	Pure	4.7
5—Sugar	Pure	5.5
6—Sugar	Pure	6.2
7—Sugar	Pure	7.0

Sample No.	Known to be:	"Vol. Pb. ppt."
8—Sugar	Pure	10.8
9—Sugar	Pure	7.6
10—Sugar	Pure	10.6
11—Sirup	Adulterated	0.8
12—Sirup	Adulterated	0.1
13—Sirup	Adulterated	0.2
14—Sirup	Partly maple	3.7
15—Sirup	Pure	7.0
18—Sirup	Pure	8.0
19—Sirup	Adulterated	0.0
20—Sirup	Adulterated	1.5
21—Sirup	Adulterated	0.2
22—Sirup	Pure	10.7
23—Sirup	Adulterated	0.0
24—Sirup	Pure	6.7
25—Sirup	Adulterated	1.0
26—Sirup	Pure	10.3
27—Sirup	Pure	10.4
28—Sirup	Pure	9.7
29—Sirup	Adulterated	0.1
30—Sirup	Adulterated	1.0
31—Sirup	Pure	7.0
32—Sirup	Adulterated	1.5
33—Sirup	Pure	10.0
34—Sirup	Adulterated	1.6
35—Sirup	Adulterated	2.7
36—Sirup	Pure	7.8
37—Sirup	Adulterated	1.3
38—Sirup	Adulterated	2.0
39—Sirup	Pure	7.9
40—Sirup	Pure	7.8
41—Sirup	Adulterated	1.7
42—Sirup	Adulterated	0.0
44—Sirup	Partly maple	5.0
49—Sirup	Pure	7.7

For the pure products in the above, the results are as follows:

	Sirups.	Sugars.
Average	8.5	7.9
Minimum	6.7	4.7
Maximum	10.7	13.6

The results on the adulterated samples are in all cases much lower than those of pure products and results on samples obtained so far have always corresponded with the complete analysis.

TWO NEW PRELIMINARY TESTS.

The Color Test.—The color of maple products was discussed under the subject "Color," and as may be readily understood, the color in pure products is due to other substances besides caramel. Since amyl alcohol does not dissolve caramel, and preliminary experiments showed that it extracted no color from adulterated or imitation products, further experiments were made on a larger number of samples. It was found that a product containing no maple never gave any color to the amyl alcohol; all pure products gave a very dicided color, most of them a dark brown; some of the light colored products gave only a pale brown color.

The test is made as follows: Put 15 c.c. of sirup, or 15 grams of sugar and water to make 15 c.c., in a test tube or glass-stoppered cylinder; add 3 c.c. of pure amyl alcohol and 1 c.c. of a 20% solution of phosphoric acid and mix the whole thoroughly by shaking; let settle and note the color of the amyl alcohol layer.

A number of preliminary tests showed that amyl alcohol alone does not in all cases dissolve enough coloring matter to give a good indication; some of the coloring matter is soluble in water and remains so unless phosphoric acid is added, which causes most of the coloring matter to go into solution in the amyl alcohol. The test gave the following results:

Sample No.	Known to be:	Color by Amyl alcohol test:
1—Sugar	Pure	Good.
3—Sugar (very dark)	Pure	Very dark.
4—Sugar	Pure	Good.
5—Sugar (light)	Pure	Fair.
6—Sugar	Pure	Good.
7—Sugar	Pure	Good.
8—Sugar (light)	Pure	Fair.
9—Sugar	Pure	Good.
10—Sugar	Pure	Good.
18—Sirup	Pure	Good.
43—Sirup	Cane and maple	Fair.
45—Sirup	Cane and maple	Trace.
46—Sirup	Pure	Good.
48—Sirup	Mostly cane	None.
51—Sirup	50% maple	Fair.
52—Sirup	Pure	Good.
53—Sirup	Cane and maple	Little color.
54—Sirup	Cane and maple	Trace.
55—Sirup	20% maple	Trace.

56—Sirup	Pure	Fair.
57—Sirup	Cane and maple	Trace.
58—Sirup	"Maple flavor"	None.
Sirup	Cane + caramel	None.

THE FOAM TEST.

This test was the result of the observation that sirups or sugars which are mostly made of cane do not give any trouble and produce hardly any foam when ignited for ash; pure maple products, on the other hand, often produce considerable foam on ignition. Preliminary experiments showed that a pure maple sirup diluted with water and shaken will produce a persistent foam, while adulterated products produce very little, and this little disappears quite rapidly. The test as now made is as follows: Place 5 c.c. of sirup into a narrow tube or cylinder graduated in tenths of a c.c.; add 10 c.c. of water and shake vigorously for half a minute; let stand ten minutes and read volume of foam.

This test gave the following results on sirups:

Sample No.	Sample known to be:	c.c. foam.
11	Partly maple	1.5
12	Partly maple	2.0
13	Adulterated	0.0
14	Partly maple	2.5
15	Pure maple	5.0
18	Pure maple	3.5
19	Adulterated	1.0
20	Adulterated	0.5
21	Adulterated	1.5
22	Pure maple	4.0
23	Adulterated	1.0
24	Pure maple	3.5
25	Adulterated	1.0
26	Pure	0.1
27	Pure	1.0
28	Pure maple	3.0
29	Adulterated	0.1
30	Partly maple	1.5
31	Pure maple	6.0
32	Adulterated	1.5
33	Pure maple	4.0
34	Adulterated	1.0
35	Adulterated	1.5
36	Pure maple	3.5

37	Adulterated	0.1
38	Adulterated	0.5
39	Pure maple	3.5
40	Pure maple	5.0
41	Adulterated	1.5
49	Pure maple	4.0
59	Adulterated	1.0

Samples 26 and 27, on complete analysis gave results of pure maple products; they had, however, a most disagreeable odor and flavor, reminding one of decomposing or putrifying nitrogenous organic matter, especially like putrifying egg albumen; these two samples were therefore not normal and but little foam was produced by each. In this list the eleven pure sirups gave an average of 4.1 c.c. foam, minimum 3.0 c.c., maximum 6.0 c.c.; the adulterated or mixed products all gave less than 3.0 c.c.

ADULTERATION.

The writer's original intention was to collect data from reported analyses to show percentage of adulteration for different years and for different localities. Such percentage figures, however, would not represent actual conditions, since in collecting samples for the analyst, the inspectors select those that are suspicious or give some indication of adulteration. In a general way it may be said that on account of the various pure food laws and pure food agitation, but few samples of fraudulent maple products are on the market; there are of course a great many, in fact the majority of maple products are mixed with cane sugar, but these cannot be classed as fraudulent if properly labeled. In some cases considerable ingenuity is displayed by the "mixers" in making a label for mixtures of maple and cane products.

Ten or fifteen years ago, the chief adulterant for maple products was glucose; some cane sugar was also used. The reasons why glucose was used were its cheapness and the fact that it prevents crystallization of sucrose. The "mixers" soon found that analysts had no difficulty in detecting glucose, and as the laws with reference to adulteration became more stringent, glucose disappeared as an adulterant, until to-day it is very rare to find a maple product with glucose. The "mixers" were not long in discovering the fact that the sugar in maple sap is identical with that found in the sugar cane, namely sucrose, and cane sugar became and still is

to-day the chief adulterant for maple products. For a number of years chemists were unable to detect the addition of cane sugar to maple products; even now there are to be found analysts who will not undertake to determine the presence of cane sugar, or the addition of an adulterant; and indeed, it is not a simple matter, and may well be left for the analyst experienced in maple products. Since no indication of adulteration can be gained by a study of the sugars, analysts have turned their attention to research on the other constituents. Some of the earliest work in this direction was done at the University of Buffalo, in the laboratory of Prof. H. M. Hill. The results of his investigations and analyses were never published, and several years before the work of other investigators was published, Prof. Hill was the only analyst in this part of the country who would undertake to analyze and detect adulteration of maple products.

As commonly used and understood, adulteration means the addition of any foreign substances; legally, and according to pure food laws, this may or may not be adulteration; a maple product is adulterated when it contains any foreign substances and is labeled or sold as pure maple; a sirup or sugar cannot be regarded as adulterated when its label tells the contents. With reference to labeling mixtures of cane and maple sirups, Food Inspection Decision 75, U. S. Department of Agriculture, says: When both maple and cane sugars are used in the production of sirup the label should be varied according to the relative proportion of the ingredients. The name of the sugar present in excess of 50% of the total sugar content should be given the greater prominence on the label; that is, should be given first. For example, a sirup the sugars of which consist of 51% cane and 49% maple should be properly branded as "Sirup made from cane and maple sugar," or as "Cane and maple sirup." The terms "maple sirup" and "maple sugar" may only be used on the label as part of the name when these substances are present in substantial quantities as ingredients. They should not appear on the label as part of the name when only a small quantity of these substances is used to give a maple flavor to the product. A cane sirup containing only enough maple to give a maple flavor is properly labeled as "Cane sirup, maple flavor," or "Cane sirup flavored with maple." The presence of cane sugar (sucrose) should be declared as *cane sugar,* and not as *white sugar.*

LEGAL STANDARDS.

A marked improvement in food legislation and pure food laws is the addition of standards for food products. In nearly all States where maple products are mentioned in the laws there is also a standard given. The standards adopted by the U. S. Department of Agriculture are given in Circular 19, and are as follows.

"*Maple sirup* is sirup made by the evaporation of maple sap or by the solution of maple concrete, and contains not more than 32% of water and not less than 0.45% of maple sirup ash."

"*Maple sugar* is the solid product resulting from the evaporation of maple sap, and contains, in the water-free substance, not less than 0.65% of maple sugar ash."

The writer is indebted to the many friends who have helped to make this article possible. I am under obligations to a number of western New York farmers for extending to me the privilege of visiting their maple groves and camps for several seasons. I am especially indebted to the following: Prof. C. H. Jones, chemist, Vermont Experiment Station; Prof. Cowell, Supt. South Park Botanical Gardens, Buffalo; Dr. Hill, Professor of Chemistry, University of Buffalo, and Mr. Frank Severance, Secretary Buffalo Historical Society.

University of Buffalo,
Buffalo, N. Y.

MINERAL PRODUCTION OF THE UNITED STATES IN 1906.

The United States Geological Survey's annual report on the mineral resources of the United States for 1906 is now ready for distribution. The separate chapters of this volume have been published from time to time as the statistics for the various minerals became available, and these assembled chapters form a book of 1300 pages, provided with a table of contents, an introduction and an index. The volume comprises 47 separate reports, prepared by 27 authors, covering entirely the mineral production of the country, with descriptions and discussions of the deposits from which the minerals are obtained, reports of imports and exports and many comparisons of home and foreign production, statements of prices and prospects, and notes on the technology of many of the products.

In its general features this volume is similar in form and scope to the preceding reports on mineral resources published by the Geological Survey, the series covering altogether a period of twenty-seven years. For twenty-five years of this period the work of gathering these statistics has been in charge of Dr. David T. Day, but the present volume has been prepared in part under the supervision of Mr. Edward W. Parker, who has been for many years Dr. Day's assistant and collaborator. Hereafter Dr. Day will give his attention chiefly to the compilation of reports on petroleum and natural gas, substances concerning which accurate information has been difficult to obtain, and Mr. Parker will have administrative charge of the work of collecting and compiling the various reports and statistics that are published in this annual volume.

Since the Survey began its work on the mineral statistics of the country the value of the mineral production has increased more than five fold. From $364,928,298 in 1880 it has risen gradually, with some fluctuations, to $1,902,517,565 in 1906, a sum representing the value of the mineral products in their first marketable condition. The larger producing States contributed to this total in 1906 in the following order and approximate proportions: Pennsylvania, 30 per cent.; Ohio, 11 per cent.; Illinois, 6 per cent.; New York and West Virginia, 4 per cent. each; Montana, Colorado, and Michigan, 3.5 per cent. each; Arizona and Missouri, 3 per cent. each; Alabama and California, 2.5 per cent. each. The value of the mineral output of each of these twelve States was more than $50,000,000, and their combined value amounted to more than $1,488,000,000.

The value of the metallic products of the country increased from $702,453,101 in 1905 to $886,110,856 in 1906; that of the non-metallic products from $921,075,619 to $1,016,194,350. As heretofore, coal and iron are our most important mineral products, the value of the coal in 1906 having been $513,079,809, and that of the iron $505,700,000. Copper is third in value, with $177,595,888; clay products are fourth, with $161,032,722; gold is fifth, with $94,373,800, and petroleum is sixth in value, with $92,444,735. It is noteworthy that the value of the silver output, $38,256,400, was exceeded by that of lead, which amounted to $39,917,442.

The greatest increase during the year is shown in the production of coal, copper, and cement.

The task of gathering the growing mass of statistics of the country's mineral production is made more exacting from year to year by the urgent demand for increased accuracy. There is no law requiring the producers to submit statistics of their production to the National Survey, and their voluntary cöoperation in this work is one of its most noteable features.

THE FRANKLIN INSTITUTE.

Ballentine's Process of Testing the Hardness and Density of Metals.

[*The Report of the Franklin Institute, through its Committee on Science and the Arts, on the Process of Testing the Hardness and Density of Metals and other Materials, devised by William I. Ballentine, of Chicago, Ill. Sub-Committee: G. H. Clamer, Chairman; A. E. Outerbridge, Jr., A. W. Allen.*]

[No. 2417.]

Before discussing this process for testing the hardness and density of metals, and other materials, it would perhaps be well to understand exactly what is meant by "Hardness." "Hardness" is that property of material which resists a change in the relative position of the molecules of the material without separating them from each other. "Hardness" may therefore be tested and recorded as "the resistance to indentation."

Quite a number of methods of testing hardness have been proposed, some of which are at present in use, the following being those which are most prominent:

1st.—Prof. Turner's method, which depends upon the weight in grams required to cause a diamond to scratch a polished surface.

2d.—The Drill test, proposed by Chas. A. Bauer, the principle involved being that with a drill running at a constant speed with a constant load, the hardness is proportionate to the number of revolutions made by the drill, and the depth of the penetration.

3rd.—The method proposed by Mr. Keep. Mr. Keep devised a machine on the same principle as that involved in the Bauer test,

but the machine has the additional device which records any variation in hardness for the full depth of the test.

4th.—This is known as the Brinell Ball Test. This method, devised by Brinell, is the one at present most extensively used. This test depends on the principle that hardness is proportionate to the indentation made by a hardened steel ball into the test sample under a constant load. Brinell has devised a machine which operates on this principle, and by measuring the diameter of the impression made, ascertaining the area of the impression in square millimeters, and then dividing this into the amount of pressure used in kilograms, the resultant figure is a numeric expression of the hardness of the material tested. This figure is called a "Hardness numeral." It is therefore possible to compare the hardness of any particular sample tested with others by simply comparing these numerals.

The above processes, it will be seen, all depend on some method of recording the resistance to indentation. In getting back to our definition of "Hardness," they record the resistance of material to a change in the relative position of the molecules of the material, without separating them from each other.

The process which has been invented by Mr. Ballentine, and which is covered by patent granted June 4th, 1907, Patent No. 855,923, presents an ingenious method and device for recording resistance to indentation. The process depends on the following fact:

> "That a known and constant weight which is allowed to fall through a known and constant distance, will exert a known and constant force upon an anvil, and if the force is transmitted to a pin which is capable of indenting the material tested, the relative hardness of the materials can be determined by the depth of indentation."

It would be an exceedingly difficult task, however, to measure this indentation accurately, and Mr. Ballentine has therefore inserted a recording disc, which is made of a softer metal than the metal being tested, and therefore receives an indentation proportionate to the resistance offered by the material tested to the indentation of the test pin.

The apparatus used consists of merely a guiding tube, a plunger, which is held at the top of the guiding tube by a trigger, and at the bottom of the tube an anvil and test pin. There is also

attached to the guide tube a spirit level, to see that the tube is held exactly in a vertical position. At the bottom of the tube there are a number of holes to allow for the escape of the air, forced out by the dropping of the plunger. The recording disc is attached to the bottom of the plunger.

The method of operating the apparatus in making a hardness test is as follows.

First:—The thickness of the recording disc is determined by a micrometer; the same is then attached to the plunger. The plunger is now held at the top of the guiding tube by the trigger, and after seeing that the guiding tube is in an exactly vertical position, as shown by the spirit level, the trigger is released. The plunger, together with the guiding disc attached to the bottom of it, descends and strikes the anvil, which is directly connected to the test pin. The result is that the test piece is indented and the recording disc is also indented or compressed. The reduced thickness of the recording disc is now measured by the micrometer, and the difference between this thickness and the original thicknes represents a numeral, which can be taken as a relative number of hardness number of the material tested. Thus, for instance, if the original thickness of the recording disc is .300 and after compression it is .200, the hardness numeral would be .100.

The principal advantage possessed by this method of testing over others which have heretofore been proposed is the fact that the apparatus is entirely portable, and can be carried to the test piece. In other forms of apparatus it is necessary to carry the test piece to the apparatus and to prepare these pieces for the purpose of testing. The Ballentine apparatus can be taken to any casting or piece of metal in the shop or foundry, and by simply flattening a very small area, a test can be made right then and there, without defacing the casting, or going to the inconvenience of cutting off a test piece and taking it to the laboratory, all of which occasions more or less inconvenience. It is by reason of the portability of the apparatus that it is particularly useful in machine shop service, it being possible to determine beforehand the hardness of a piece to be machined, thereby guaging to a certain extent the proper speed and cut which should be taken in machining.

The following is a list of the tests which were made by this method, which show that the results were quite concordant:

HARDNESS OF BABBITT METAL.

Link-Belt Company,
Chicago, April 23d, 1907.

Recording Disc No.	Thickness before test	Thickness after test	Penetration, or record of hardness	Test piece mark	Kind of metal
1.	.29680	.22555	.07125	A	From the Hoyt
2.	.29785	.22800	.06985	A	Metal Co., St.
3.	.29725	.23230	.06495	B	Louis
4.	.29760	.23555	.06205	B	
5.	.29692	.24130	.05562	C	
6.	.29738	.24155	.05583	C	
7.	.29923	.22730	.07193	I	Copper Hard
8.	.28697	.22840	.06857	I	" " Babb
9.	.29692	.24975	.04617	II	Common Babb't
10.	.29745	.25435	.04310	II	" "
11.	.29788	.28975	.00813	III	Lead
12.	.29680	.28922	.00758	III	"
13.	.29793	.22145	.07648	IIII	Bearing Metal
14.	.29725	.21890	.07835	IIII	

The Chairman of the Committee has also made a number of tests to determine the accuracy of the device, with the following results:

First—Special Babbitt.

1st Test..... .1005
2d " ..... .1010
3d " ..... .1022

Second—Plastic Bronze.

1st Test..... .1245
2d " ..... .1244
3d " ..... .1242

Third—Genuine Babbitt.

1st Test..... .1155
2d " ..... .1147
3d " ..... .1165

Fourth—Phosphor Bronze.

1st Test..... .1310
2d " ..... .130
3d " ..... .1282

Fifth—Plumbic Bronze.

1st Test..... .0996
2d " ..... .0945
3d " ..... .090

Sixth—Copper, cut from ingot.

1st Test..... .130
2d " ..... .131

Attention is called to the fact that although the title of Mr. Ballentine's patent is "A Process of Testing the Hardness and Density of Metals and other Materials," the process, as a matter of fact, is a process of testing Hardness only, which properly is entirely distinct from what is technically known as "Density." Tests for hardness as made do not record the density.

The following tests, which were made of a cast-iron wedge, test No. 1 being in the thickest part of the wedge, test being made at uniform distance between tests No. 1 and No. 14, along a central line drawn on the face of the wedge. Tests No. 15 and No. 16 were made nearer the bottom of the wedge, and intermediate between the central line and the edge. Tests are as follows:

Test No.	Thickness of Disc before test INCH	Thickness of Disc after test INCH	Penetration INCH
1.	0.28890	0.15665	0.13225
2.	0.28870	0.15585	0.13285
3.	0.28880	0.15430	0.13450
4.	0.28895	0.15360	0.13535
5.	0.28915	0.15325	0.13590
6.	0.28875	0.15375	0.13500
7.	0.28910	0.15400	0.13510
8.	0.28865	0.15355	0.13510
9.	0.28895	0.15352	0.13543
10.	0.28915	0.15377	0.13538
11.	0.28900	0.15312	0.13688
12.	0.28900	0.15295	0.13605
13.	0.28950	0.15267	0.13683
14.	0.28860	0.15210	0.13650
15.	0.28900	0.15280	0.13620
16.	0.28920	0.15153	0.13767

In consideration of the ingenuity and novelty of the process as above described, and the value of a simple and convenient method and apparatus for testing the Hardness and Density of metals, in both practical and scientific application, as has been invented by Mr. Wm. I. Ballentine, the Institute recommends the award of the John Scott Legacy Medal and Premium.

Attest: WM. H. WAHL, *Secretary.*

Philadelphia, April 1, 1908.

REPORT OF LUMBER PRODUCTION OF THE LAKE STATES.

The Lake States, one of the greatest forest regions that ever contributed to the lumbering activities of any country, are rapidly falling behind in timber production, according to a preliminary statement just issued by the Bureau of Census.

Statistics concerning the annual output of forest products, collected by the Bureau of the Census in coöperation with the United States Forest Service, from more than 2,100 saw-mill operators in Michigan, Wisconsin and Minnesota—the big three—have shown that the cut last year was only five and a-half billion feet of lumber, a big pile, yet 12 per cent. less than the cut of the preceding year.

The heavy inroads made in the exploitation of the timber resources of the large lumber States on the Great Lakes have been too much for the great forests, and the amount available for cutting is getting lower each year. The decadence of the lumbering industry in this region is forcefully illustrated in the drop in the white pine cut during the past ten years. Michigan's forests of this valuable tree were the richest in the wo ld and were often said to be inexhaustible. The folly of such a statement is shown by the report that the cut of white pine in Michigan last year was only one-fourth of what is was in 1899, only eight years before.

In lumbering the forests no thought was given to anything but immediate money returns, and consequently the countless fires running over the land, after the timber was stripped, have killed young growth over wide areas and greatly impoverished the soil. Now 6,000,000 acres, or nearly one-sixth of the State of Michigan, known as the "pine barrens," have been thrown on the delinquent tax list and are a burden to the people. Under proper forest management this land would have been producing timber to-day. Between 1899 and last year the white pine production fell off nearly as much in Wisconsin as in Michigan. In Minnesota, the State which now contains the largest amount of virgin white pine, the decrease in the same period was nearly one-third.

Taking the three States together, pine constituted nearly forty-six per cent. of the total lumber production in 1907, hemlock a little more than twenty-seven per cent. and maple ten per cent., the balance being made up mostly of basswood, birch, tamarack, elm, beech, oak, spruce, ash, and cedar, in the order given. The pine is mostly white and Norway, which are grouped together under the general trade term of "northern pine." Pine made up over nine-tenths of the lumber produced in Minnesota, one-third of that produced in Wisconsin, and less than two-fifths of the total cut of Michigan.

Along with this great decrease in pine, there have been relatively as heavy decreases in the most valuable of the hardwoods, oak, elm, and ash. Little more than one-fifth as much oak was cut in the Lake States last year, for instance, as in 1899, while the cut of elm and ash was but half of that of eight years earlier. As is always the case, the decreasing supplies of the more valuable woods have caused those once considered of little or no value to be drawn upon heavily. This has been particularly true with hemlock, so that now more hemlock than pine lumber is manufactured in Wisconsin, and twice as much hemlock as pine cut in Michigan. There have been heavy increases in the use of maple, birch, and beech within the past few years, but the maximum cut of these species is probably near at hand; and taking all of the hardwoods together, there has been a slight falling off since 1899.

ELECTRICAL SECTION.

(Stated meeting held Thursday, November 5, 1908.)

Electricity in Refrigeration.

By R. Louis Lloyd.

It is probably not necessary for me to discourse here on the reasons why ice, or its counterpart, artificial cold, are of such importance in the commercial world to-day: how by segregation and civilization mankind has desires and necessities which rise above the immediate provisions of nature, desires which can be satisfied only by the supply of articles inherently poorly adapted existence if natural conditions only prevail.

Artificial warmth, artificial light, artificial power, artificial cold are necessities of civilization. And as necessity is the mother of invention, our engineers have supplied the refrigerating machine. The constantly increasing contamination of our water courses and other bodies of water where ice was harvested, has been a potent factor toward the rapid introduction of machines for ice making. Latter-year improvements have so enhanced the efficiency of the small sizes that the demand has been continually augmented, with the natural result of turning to the electric motor as the most convenient, simple and economical driving power.

The management of our local public electric service company early recognized the enormous possibilities of electric refrigeration and have done much toward popularizing and pushing its use. The results have been very gratifying, and Philadelphia can probably show to-day a larger number of small sizes of refrigerating machines than any city similarly situated. They enter into almost every line of business handling perishable goods, not even omitting the undertaker and the morgue.

I can probably not do better than give you a description of a few of the equipments now in operation in the several lines. We will

consider first the outfit of a retail meat shop in the upper part of the city where a "baby" Larsen-Baker compressor is operated by a three H.P. motor. The machine is set up in the basement under the meat box, which is on the floor above. This box is 9′ x 6′ x 11′ high, and holds at times as much as six sides of beef, four or five calves and a dozen lambs, a total of a ton and a half of meat. This is a direct expansion system with a brine tank auxiliary for storage. This tank takes the place of the ice bunker in an ordinary meat box and will hold the temperature down low during the non-operative hours of the machine. With a temperature of 34 degrees when shutting off at night, a rise of only four degrees will be experienced by morning.

In addition to the main box, the counter cases in the store and a corn-beef tank are also refrigerated.

At this time of the year, four hours operation per day is sufficient. In summer about nine hours are necessary, while during January and February the machine is not used at all, unless an unusually hot spell visits us. When ice was used, the yearly bill was $425. The power bill for the first year was $250 and for the second $207. This installation cost less than $1000. Adding interest and depreciation charges at 15% to the power bill makes the total operating cost $360 per year, a saving of 14%. To say nothing of the added advantages of lower temperature, more constantly supplied, dry cold and an improved display counter which increases trade.

In contrast let us turn to a large installation for a combined wholesale and retail meat business. It consists of two 25-ton Vilter refrigerating machines, each driven by a fifty H.P. Northern motor, chain geared; one Triplex plunger brine pump, driven by a 5 H.P. motor; one deep-well pump, driven by a $3\frac{3}{4}$ H.P. motor; one large refrigerator box or cooler 60′ x 17′; three small refrigerator boxes or freezers 20′ x 17′; one pickling room 37′ x 19′ x 11′ high; one brine tank 19′ x 5′ x 8′ deep, situated in the latter room. About 5000 gallons of brine.

The system is brine circulation exclusively, all of the expansion coils being located in the brine tank. Three or four hours' operation of the machine is usually sufficient to reduce the temperature of the brine to five or eight degrees above zero. It is then pumped through pipes in the freezers and the bunker of the cooler during six hours, which keeps these rooms at the proper

temperature. After a shut-down of about fifteen or twenty hours this brine has risen to about fifteen degrees.

The object of putting in two refrigerating machines was to permit one machine to rest during the heavy duty in summer and also to allow for growth of the business. The two have never yet been needed both working at the same time. In fact, six hours' work in twenty-four for one machine in the hottest summer weather so far encountered has been found ample. In winter weather one hour's work for the machine and about one and one-half hours' operation for the brine pump is all that is required to produce the desired temperature.

The cooler usually holds about 20,000 pounds of meat. and is maintained at thirty-five degrees. This box is well insulated with layers of cork laid in asphalt pitch. There are three doorways in this box and it is well lighted by incandescent globes.

The wall and counter cases in the store are also cooled by brine pipes located above in the former, and at the bottom of the latter. This permits of the display of choice cuts of meat without fear of deterioration.

The freezer was divided into three rooms in order to accomplish better results and allow considerable elasticity in the accommodations. In certain seasons of the year it is necessary to take care of more of those delicacies which require the very low temperature; and as arranged one, two or three sections can be utilized independently. The temperature can be brought as low as zero in any of these rooms if necessary. Fifteen degrees, however, is found to be ordinarily sufficient.

The pickling room is cold enough at thirty-five degrees, but on account of the presence of the brine tank, the temperature is usually down to thirty degrees without circulation in the coils of this room.

Since the plant was put into operation, in the early spring of 1907, there has not been the slightest delay or trouble from the equipment. It has operated on a 20% load factor and the results have been entirely satisfactory.

The condensing water is obtained from an artesian well, the water being pumped from a sixty-foot depth by a $3\frac{3}{4}$ H.P. motor, above mentioned.

It is rather difficult to make any comparisan between the cost of operation of this equipment and the cost of ice. Of course

the freezers could not have been used and the low temperatures of the other boxes could not have been maintained. Outside storage charges would have been incurred. The heaviest consumption was 4017 K.W. hours for the month of July, and he lightest 1420 K.W. hours in January. The owner of this plant is highly gratified with its operation.

Early in 1907 the Leo. Niessen Co. installed a six-ton machine

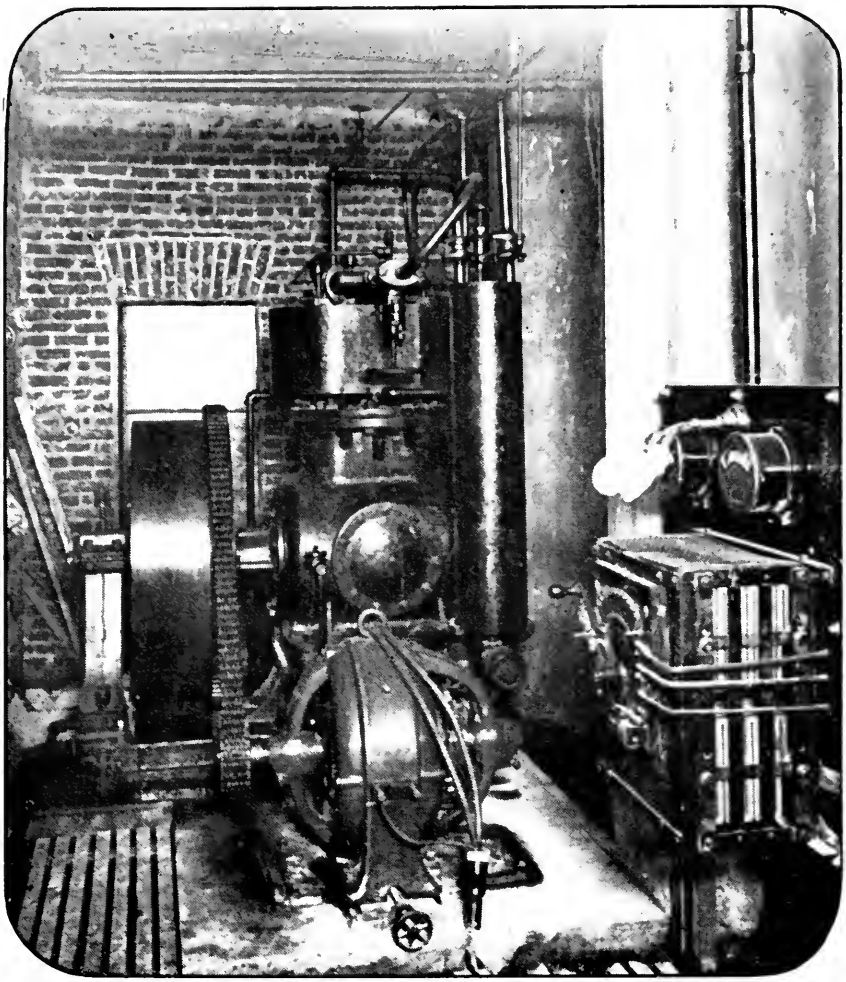


Fig. 1. Six ton refrigeration machine and motor. Silent chain drive.

to take care of their immense stock of flowers in two refrigerators of their new store. See Fig. 1. One box is in the basement and is used for smilax and green stuff. This is 8′x20′ internal dimensions and 8′ high. The desired temperature is thirty-two degrees. The system used is direct expansion with brine tank auxiliary. After fresh crates and boxes have been put away and the temperature has risen ten or fifteen degrees, one hour's operation of the ma-

chine will bring the temperature down to thirty-two degrees. The valves feeding this box are then closed, and the work of the machine is all done in the main box in the store. This one is 40′ x 10′ x 12′ high, has two doors and two electric lights. They are burning almost constantly and the doors are open every few minutes throughout the day, which lasts from 7 A.M. to 9 P.M. This box has two brine tanks the length of the box, 3′ deep x 15″ wide. They each contain 300 gallons of brine. All the cooling tubes are in and around these tanks. For the better circulation of the air and to obtain a more uniform temperature, air flues are built on both sides extending to within two feet of the floor. The refrigeration is produced in a sort of a trough which prevents the cold air falling immediately against the flowers on the upper racks. The flues carry it down the sides to be distributed below.

Three to five hours per day the year through is all that this machine is required to operate. It is giving highly satisfactory service and has needed no repairs to date—nearly two years. The bills for power have varied from $43 to $63 per month. This would buy less than half a ton of ice per day. Three times this much ice would not give them equivalent results of cooling. The load factor of the motor for the year is about 40%.

Early last year the proprietors of one of our most prominent retail florist shops decided to adopt mechanical refrigeration.

They had a very handsome display case along the east wall of their establishment, 16½′ long and 9′ high and 42″ wide, embracing about 500 cubic feet. It consisted of a show case with three shelves, drawers below, and an ice bunker above.

These shelves hold jars and vases of cut flowers in water, and they were usually kept full at all times, forty jars holding probably 200 or 300 pounds of water, being the average quantity, and this was renewed daily.

The drawers below contained the smilax and green stuff and were well filled. Openings in the floor and the main case permitted the coldest air to circulate down to and around these goods. Both doors and drawers were opened frequently. There were four of each and the openings would average probably four times per hour each.

Under these conditions it was found necessary to use 500 to 700 pounds of ice each day to maintain a temperature of 54 to 55 degrees.

The annoyance and inconvenience of handling were great. The ice bill for one year was $501. We contended that the cost of power to operate a refrigerating machine to produce equal results would not be over half this amount. A contract was made for a Brunswick refrigerating machine of one ton capacity, which was guaranteed to produce the desired results. The cost of the complete installation in operating condition was a little over $1000. The installation was completed and the machine operating the last week in May, 1907.

In the ice bunker above the case four narrow brine tanks 14′ 9″ long 18″ high and 4″ wide were placed, and the ammonia expansion pipes led into them. Each tank was cooled by 100 feet of one-inch pipe, bent zig-zag and arranged in seven rows each 14′ long. One barrel, or 350 pounds of calcium chloride salt was dissolved in enough water to fill these four tanks, making a weak solution, Sp. Gr. 1.05, with a freezing point just below 26 degrees F. The idea was to freeze this solid and have a result similar to that obtained from ice.

It worked out admirably in practice. At eight in the morning, when the store is opened, the machine is started in operation. The temperature in the cases at this time is found to be just about as it was left the night before, about 45 degrees. They now renew the vases and jars and put in fresh flowers from the hot house. The doors are opened constantly for quite a while, and the temperature rises in the cases sometimes as high as 60 degrees. This will naturally vary at the different seasons of the year, depending upon the temperature of the room, and the water supply. The cases are soon brought down to the desired temperature, and toward evening the tanks will have frozen solid again. The machine is then stopped and remains so over night.

The results have been very satisfactory, and the avoidance of the bother and trouble of handling ice is in itself justification for making the change.

The proprietors have ordered that the machine be overhauled every year, a preventative measure.

This is the way the account stands for the first year:

Cost of electric power	$301.07
Interest, depreciation and repairs	157.00
	$458.07
As compared to ice	501.00
Saving	$43 00

This is numerically not very large, but we must also consider the absence of labor and abuse of this fine case incident to the continual filling of the ice chamber when ice was used. These costs actually existed though not readily shown.

The motor used is a three H.P. Peerless. A test shows it to be taking almost two K.W. as a steady input. It is belted direct to the driving pulley of the machine, which runs at 280 revolutions per minute.

Next is a dairy which handles 4000 quarts of milk per day and requires nine wagons for delivery purposes. The refrigerating machine used is an eight-ton Buffalo plant, driven by a fifteen H.P. motor. The expansion coils are all submerged in a large brine tank situated above the refrigerator box, containing 2000 gallons of calcium chloride brine. Eight or ten hours operation cools this mass to 10 deg. or 20 deg. F. above zero. It is kept in motion by a small pump operating twelve or fifteen hours out of twenty-four, which also circulates it through the cooling coils of the pasteurizer. Two hours are required to pasteurize the 100 cans of milk. This is a continuous process with the improved apparatus and after heating it is rapidly cooled to 40 deg., bottled and set in the refrigerator. This latter is a well insulated room, 26′ x 14′ with 10″ walls. About six feet of the rear end is partitioned off for a sort of a freezer for the better keeping of the cream. This part is cooled as low as 28 deg. The main room ranges from 32 deg. to 40 deg.

The electric power for an entire twelve months for this refrigerating machine was $786, with a K.W. hour consumption of 17403. We notice, however, that the individual months varied greatly, ranging from 2832 in July to none at all in February. The load factor for the year was 50.7%. This is somewhat lower than the average load factor for dairies.

We will now turn our attention to a soda fountain. This, with its counterpart, the saloon installation, is the most difficult yet encountered to properly care for. The requirement of having the beverage served at nearly a freezing temperature and at the same time to constantly avoid its freezing up in the pipes, makes the problem. It is overcome by what is called sweet water circulation. The freezing coils are submerged in a tank of ordinary water of considerable volume. Some ice is allowed to form in this tank, but inasmuch as ice is a non-conductor it acts some-

what as a barrier to further formation after the first coating of a half inch or so. In addition the water is kept in constant circulation during the cooling process. (See Fig. 2.)

The plant in question consists of a three-ton Brunswick refrigerating machine, driven by a $7\frac{1}{2}$ H.P. motor. The water tank is probably 15′ x 4′ x 3′ deep and contains all the expansion coils. A small rotary pump, requiring $\frac{1}{4}$ H.P., direct connected to a motor, keeps the water in almost constant circulation from the

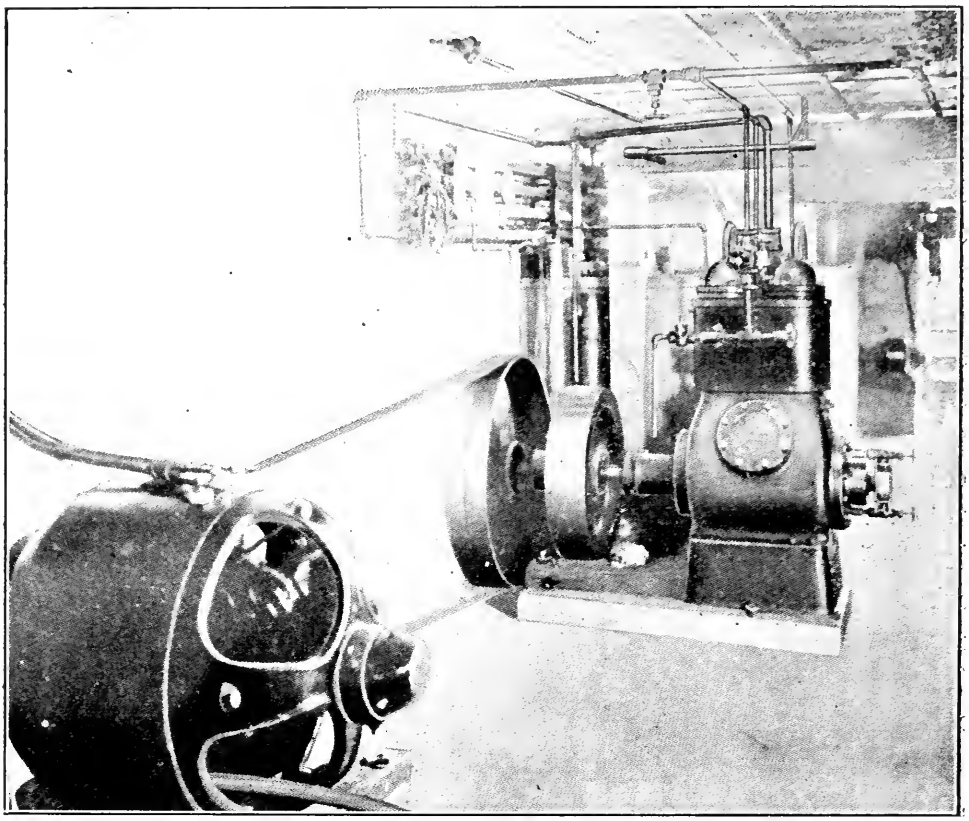


Fig. 2. Three ton refrigerating machine and motor. Belt drive.

tank through three soda fountains and return. The pipe leading from the tank through the pump carries the water at nearly 32 deg. temperature up into the lower compartments of the three fountains in sequence, then up into the coil chamber where it discharges over the soda water pipes, overflowing to the next fountain, and to the last in turn, from which it is returned to the cooling tank.

The operation is found very satisfactory, giving considerably lower temperature to the beverages than was obtained from ice.

The power bill is about one-half the former ice bill, and the confusion, delay and slop of ice deliveries avoided. Total K.W. hours for one year 11428, which is a load factor of 61%. The power used in the hottest month, August, was nearly double that of the cold month, January. The average running time of the compressor was about five hours, while the pump has of late been running continually. It was found that the soda water coils were too long getting chilled in the morning after an all-night rest in the hot store. This loss could no doubt be avoided if a little more attention were given to insulation of soda fountains.

I quote from an article in September, "Ice and Refrigeration," describing a modern bakery at Columbus, Ohio. "At first thought it may seem that refrigeration could have little to do with baking bread, but as a matter of fact it is the refrigerating machine that gives the baker the control over the processes of bread making requisite to the ensuring of the all-important uniformity in product now demanded by the customer."

All the new bakeries use refrigerating machines. Not only the bread bakers, but pie bakers as well. One of the most, if not the most modern and up-to-date establishment of its kind in the world is just about completed and beginning to do business on Tenth Street below Walnut. The Horn & Hardart Baking Company have spent $275,000 in building and equipping this new food-factory to supply the needs of its numerous "Automats" and restaurants, doing strictly a light lunch business. The refrigerating feature is worthy of our attention. (See Fig. 3.) It consists of two eight-ton units, belt-driven from a main shaft so arranged with clutch pulleys that one, or both, or neither can be operated at will. A 40 H.P. motor turns the shaft. The artesian well pump is also connected to the same and operates continuously with either refrigerating machine. Direct expansion, with still brine storage, is used in each of the six refrigerator boxes, the largest of which is the pastry box in the bakery proper. This is 50′ x 10′ x 8′ high, and will hold more pies and things than are consumed by a regiment. The fruit box is just half this size. The meat box is 20′ x 10′. Two small boxes take care of the butter and the immediate supplies for the lunch counters in the building. There are in addition an eight-can ice cream cabinet, an ice storage room and two Tyson Ice-Cream machines. The ice storage room has a capacity of five tons of ice. On one side of this room is erected

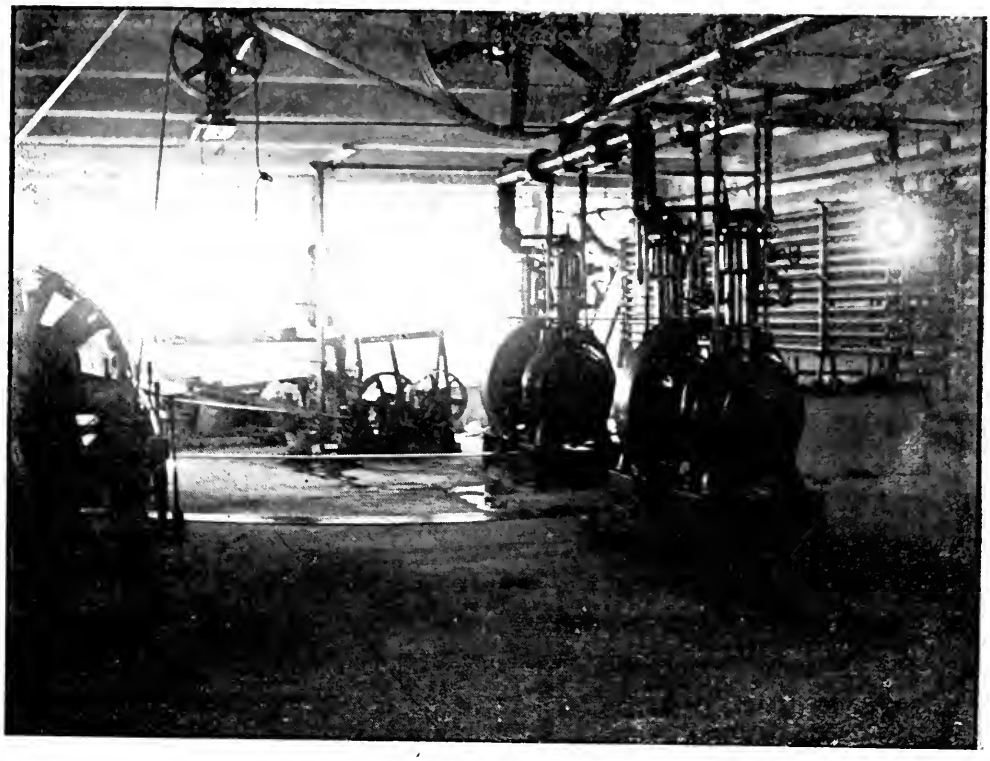


Fig. 3. Two eight ton refrigerating machines in parallel.

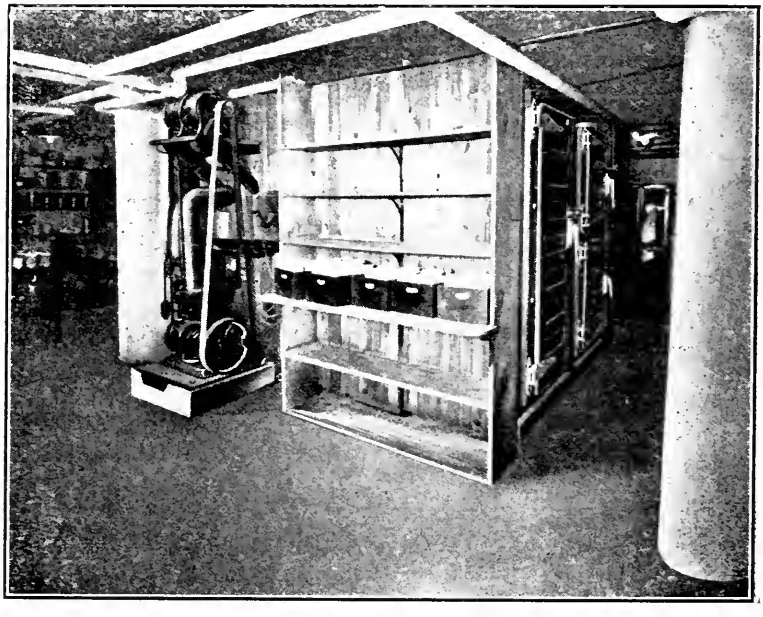


Fig. 4. One-quarter ton refrigerating machine and ice-box.

a double pipe brine cooler, which rapidly chills to zero F. the brine for circulation through the ice cream machines. The temperature of this room is usually about 23 deg.

A restaurant naturally must use some ice. A machine hardly fills the bill for iced tea, lemonade, etc., at least not yet. Several years ago Horn & Hardart became convinced that more of the ice they paid for was lost through melting to waste than was actually used. In each of their restaurants they have installed a small Brunswick machine of quarter ton capacity, to keep their ice from melting. It saves them money. Incidentally it helps cool the food stored in the same box. (See Fig. 4.)

Mr. M. is a confectioner and ice cream maker, enjoying a large retail trade. He uses one ice cream machine, turning out forty quarts at a batch and makes from 200 to 800 quarts per day. The average production during the time covered by this record has been 400 quarts per day, six days a week. The larger portion is sold and served in his parlors, although considerable is sent out on orders. This necessitates the use of some salt and ice. It is a disputed question under such circumstances whether it pays to buy this amount of ice or to put in a plant large enough to make the small quantity which will be required. Leaving occasional unusual conditions out of consideration, it may be stated as a fact that where ice can be purchased for $3.50 or less per ton, there is no economy in making one's own supply. (See Fig. 5.)

The equipment here consists of a two-ton refrigerating machine, belt-driven by a 5 H.P. 2-phase General Electric motor. It is operated nine to fifteen hours per day and cools a large body of brine in a tank 8½′ long 2½′ wide and 3½′ deep sunk in the floor of the basement. Space was at a premium even before the machine was installed, so for the brine tank the cellar floor was excavated and the top of this tank made flush with the floor. The ammonia expansion or coiling pipes are situated in this tank. There is also a brine cooler here, the object of which is to rapidly cool a small portion of the brine just before it is carried out to the ice-cream machine. The brine is circulated from this tank by a No. 5 Gould rotary pump (shown white to the right and below the center of the illustration) to three ice-cream cabinets, two in the basement for storage; one, the serving cabinet, up in the store. Two of these are each 6′ long 2½′ wide and 2½′ deep and hold twelve 40-quart cans of ice cream. The serving cabinet holds

twelve cans of different sizes, is well insulated and fitted with a movable top, so that the cans can be lifted out when cleaning is necessary. The third cabinet holds twelve 20-quart cans, making the entire storage capacity equal 950 quarts. These are each on a separate circuit of the brine piping, which branches just beyond the pump. Each line carries a check valve to prevent back flow. The refrigerating machine is operated nine to fifteen hours daily, depending on the weather and amount of ice-cream

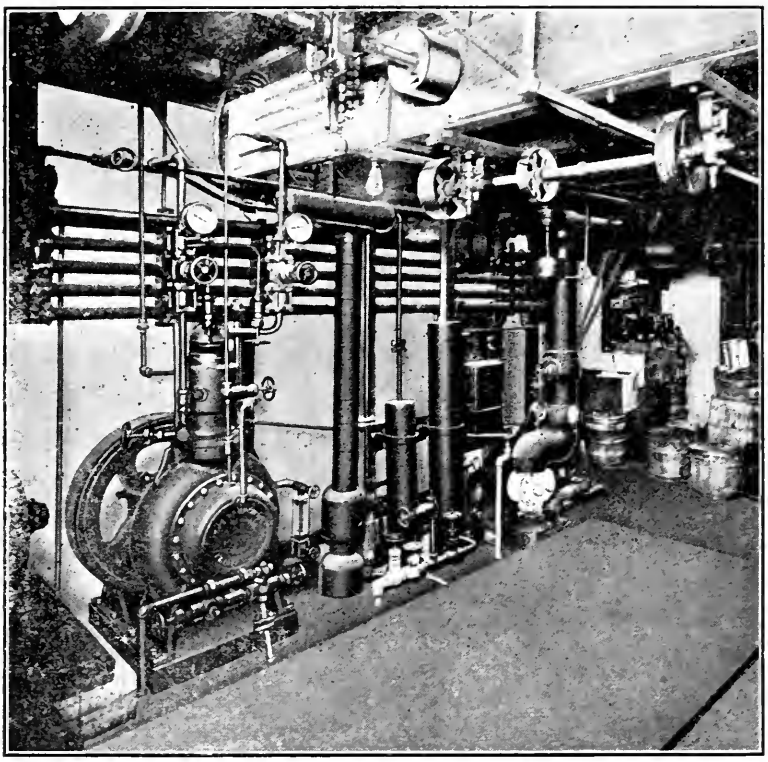


Fig. 5. Two ton refrigerating machine and brine pump. Note cover of the brine-tank in foreground.

made. The brine is kept normally at 4° to 8° F. It is generally brought down to the lower figure at night just before shut down, and in the morning the temperature will have risen to 9° or 10°.

The pipe and cabinets are all well insulated and the heat leakage kept at a minimum. This installation has been in operation during two summers and has proven its worth. Let us glance at some figures.

The cost of operation for three summer months stands as follows:

Ice, 112 tons, at $3.00	$336.00
Salt, 560 bushels, at .35	196.00
Electric power, oil fuses, etc.	227.61
Interest and depreciation	81.25
Repairs	5.00
	$845.86

Compare these with the cost for a similar period before the machine was introduced:

Ice, 208 tons, at $3.00	$624.00
Salt, 1200 bushels, at .35	420.00
Electric power	104.76
Labor, one man, $40	120.00
	$1268.76

Saving in first summer, $422.90.

The item of $5.00 for repairs charged above is inserted to be conservative. As a matter of fact there were no repairs. At the end of the year the machine was overhauled as a matter of precaution, and a charge of $20 incurred. It must not be supposed that the full year will show a saving proportionate to these three months. There are many reasons why it does not, such as labor, change of business from parlor serving to delivery, efficiency of machinery at reduced load, etc. The entire year shows less than twice this figure, but even that is a pretty good investment.

And this is not all. There is probably no business where wet floors and general dampness are more unavoidable or more unhealthy than this, where salt and low temperature must be used. Artificial refrigeration does away with it. This alone should promote its adoption, and when the new dry insulated ice cream carriers become more widely known and used, the ice-cream man will have reached his ideal.

It is our opinion that the near future will show a rapid development in the use of refrigeration equipment for apartment houses and for drinking water systems in office buildings, schools, and public institutions of all kinds. Installations of this character have been used and have proven their value. An apartment house in Chicago has, for ten years, been furnishing ice and refrigeration service from one large centralized plant to ice boxes in each of its one hundred apartments, with very satisfactory results. Flat houses in our city now in contemplation include similar equipment in their plans.

Individual machines suitable for apartments or large residences are in the market and make a very neat and compact arrangement, which allows us to ignore the ice man and his troubles. An electric motor of one horse power size is all that is

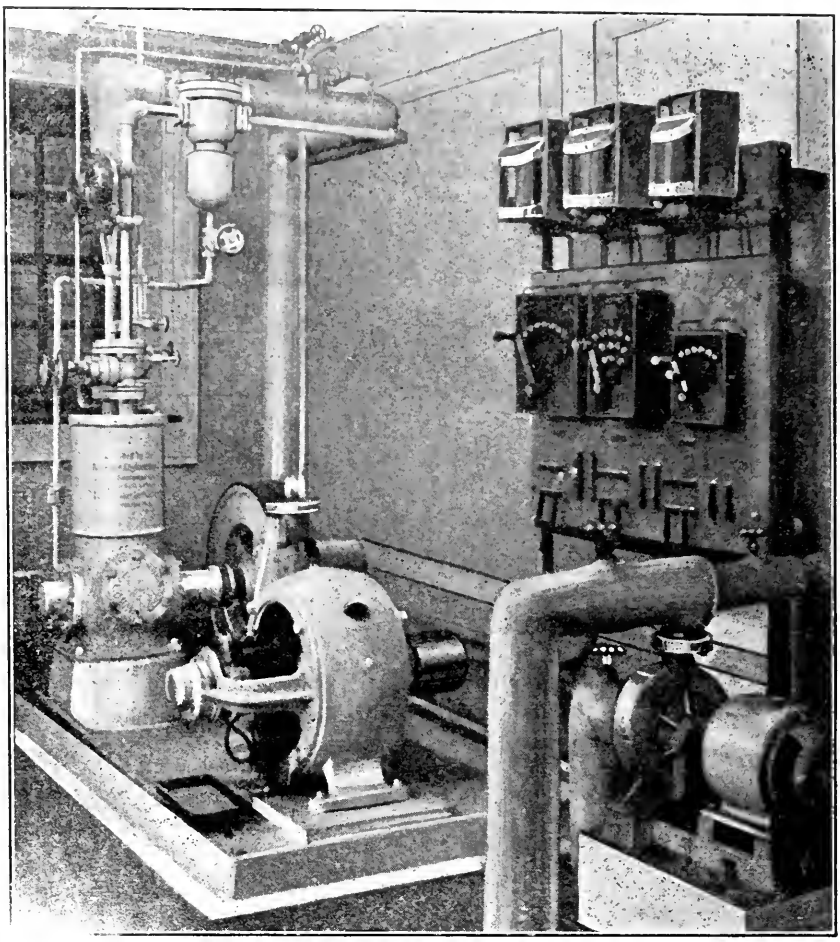


Fig. 6. Small Larsen-Baker machine for cooling drinking water Pump at the right circulates the water through the building. Each has its individual motor.

needed. The machine is rated as one-quarter ton or one-eighth ton, and will make a small cake of ice for table use as well as keep the box cold. (See Fig. 7.)

Many office buildings are equipped with a cold drinking water system which saves a great amount of running up and down carrying ice every morning. (See Fig. 6.) This illustration shows the machine in the building of the Philadelphia Elec-

tric Company which performs this service. It is a two-ton Larsen-Baker outfit, and will cool enough water for two or three times the number of people it now supplies. The expansion coils are submerged in a tank of filtered water and cools it to the desired temperature, usually about 40°. Prevalent popular sentiment calls for drinking water freezing cold. This is a great mistake, and nine out of ten people would pronounce 45°

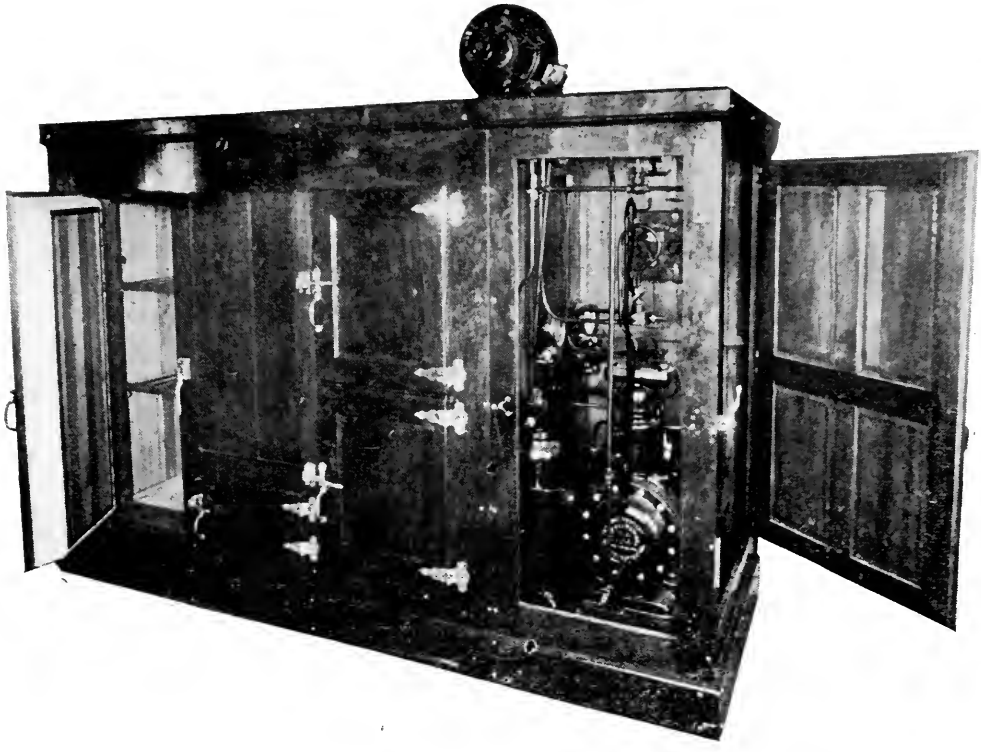


Fig. 7. Brunswick residence type refrigerating outfit and box complete with electric motor.

quite cold enough if unaware of the actual thermometer temperature. From the cooling tank the water is circulated through the building by a small rotary pump, which runs constantly during office hours. The refrigerating machine runs only a few hours out of the twenty-four.

The accompanying table gives figures taken from actual experience and shows the amounts of power used for artificial refrigeration in several lines of business.

	Tons	H.P.	Notes	Kilowatt Hours. Yearly L. E.	Total year	Monthly Ave.	Largest Month.	Smallest Month.	Summer Mon. Ave.	Winter Mon. Ave.	Spring & Fall Ave
Dairy	15	30		48.4%	33351	2779	5293 July	00 Feb.	4801	503	3034
Dairy	3	7	5 H.P. motor on bottle washer included.	56.1%	15463	1288	2294 July	173 Dec.	2069	292	1505
Residence	¼	1		47.5%	1112	93	141 July	42 Feb.	135.6	61.5	83.4
Saloon	3	7½	1 H.P. motor on brine pump included.	62.5%	12438	1036	1383 Sept.	648 Feb.	1288	677	926
Soda Fountain	3	7½	½ H.P. motor on pump included	61 %	11428	952	1318 Aug.	713 Jan.	1050	842	964
Hotel	4	10	1 H.P. motor on brine pump included.	101 %	25500	2125	2760 Aug.	1663 Feb.	2604	1687	2084
Ice Cream	2	5	7 H.P. motor on pump and ice-cream machine included.	54.5%	15008	1250	2023 Aug.	975 Jan.	1830	1164	126
Meat Dealer	1	3	½ H.P. motor on meat chopper included.	48.3%	3955	329	731 July	1 Feb.	706	56	226
Meat, wholesale	35	50		107.9%	123906	10325	28492 July	0 Feb.	23021	1977	5978
Florist, wholesale	6	12		40 %	11046	920	1419 June	580 Jan.	1190	618	953
Butcher	6	15	2 H.P. motor on meat chopper included.	26 %	9275	773	1755 July	155 Feb.	1604	208	700
Florist	1	3		72.6%	5103	425	505 July	311 Feb.	465	334	381

And now I want to say a few words about insulation. Get good insulation. This is paramount. Insulation on a refrigerator is like your clothing in winter. It is all very well to have an abundance of energy and life in your body, but if it is not suitably covered, "Jack Frost" will in the end prevail. So with cooled compartments, pipes, cabinets and ice chests. Here is your small, comparatively so, be it ever so large, refrigerated space and all around is nature's heat fighting to get in and equalize the temperature. Now, the greater the barrier, the better the insulation, the easier is it to keep out the heat. One might have ever so good a machine and be able to remove the heat from a refrigerator very expediciously, but if more heat is constantly leaking in, the machine will have to operate just that much longer, and *that* is the work which costs the money in artificial refrigeration. That is the *continual* expense while outlay for insulation occurs but *once* and brings big returns when done well.

ACETYLENE RULES MODIFIED BY THE NATIONAL BOARD OF FIRE UNDERWRITERS.

The rules formulated by the National Board of Fire Underwriters for the acetylene industry have hitherto required outside installation of acetylene generators, and while, as a matter of fact, in by far the largest part of the United States this rule has not been insisted upon, in certain limited sections it has been rigidly enforced.

The existence of a rule prohibiting the installation of an acetylene generator in an insured building was a constant menace and handicap to the industry, and its enforcement in some sections and not in others placed insurance companies in the inconsistent position of insuring property in one State under conditions which it would not accept in another. An investigation by the National Board, as to the exact condition of the industry, disclosed the fact that, in those sections where inside installation had been permitted, acetylene was proving itself to be a safer illuminant than those which it replaced.

The National Board of Fire Underwriters, at its Executive Committee meeting on January 30th, 1908, held in New York City, after considering the various favorable reports submitted to it by its various committees, amended the rules covering the installation and use of acetylene generators by striking out such words as prohibited inside installation under all conditions and substituted the following: "Generators, especially in closely built up districts, should preferably be placed outside of insured buildings in generator houses constructed and located in compliance with Rule 9."

It will be seen at once that while the National Board recommends outside installation as being ideal, in place of the absolute prohibition, the rules now mean that in all outlying districts generators may be placed in-

side, but in closely built up districts it recommends outside installation as its preference.

Even where outside installation is preferred the rule regarding construction of generator houses has been modified, and where such houses formerly had to be fire-proof, constructed of brick and located as far as practicable from other buildings, such houses may now be located adjoining an insured building and fire-proof construction is not required.

It will be seen that the above modifications are radical and are a most favorable indication of the fact that inventive genius and a close adherence to the rules of the National Board of Fire Underwriters have received a deserved recognition.

The acetylene industry has been subject to the rules of the National Board from its inception, and has loyally endeavored to meet all insurance requirements, not only in letter but in spirit. The result has been a vast expansion of the industry and a growing safety of the illuminant until the above modifications were deemed warranted by the National Board.

The investigations which were set on foot for the purpose of ascertaining facts brought forth the conclusion that, in view of the fact that the number of acetylene generators installed inside of buildings had very largely increased in the past few years, while, at the same time, the fire records seemed to show that the number of fires ascribed to such installations had if anything decreased, the rules of the National Board covering the construction and installation of acetylene apparatus had apparently safeguarded the hazard to a great extent.

The fact was demonstrated that acetylene illumination generally replaces methods which entail an equal if not a greater hazard.

Consideration was given to the fact that outside installation of acetylene generators was frequently impracticable on account of climatic conditions.

The facts disclosed by the investigation made a modification of the rules inevitable, and it was agreed that the time had arrived when the rule as to outside installation might be properly modified so that it would recommend outside location as being the ideal location, yet permitting, under proper restrictions, the location of the generator inside of an insured building.

The rules of the National Board are not mandatory, and in some sections of the country the rule regarding outside installation was not followed, but in certain sections of the country, notably New England, Suburban Philadelphia, and the Southeastern States, this rule was enforced. Some manufacturers of generators were therefore brought into competition with inferior generators, which had not the approval of the National Board of Fire Underwriters, and as both the permitted generator and the unpermitted generator must be put outside, if the rule was enforced, the competition was of such a nature that the manufacturer of a first-class generator had difficulty in surviving.

The modification of the rule will undoubtedly give a distinct advantage to the manufacturer of a permitted generator, and will draw the industry into closer alliance and loyal adherence to the excellent rules of the National Board. This relief and additional advantage to the manufacturer of a good generator means undoubtedly the practical elimination of what is known in the trade as the "tin-can generator," which, by the way, it is authoritatively stated has been the cause of eighty-five per cent. of the troubles which have arisen from the use of acetylene.

If the industry understands clearly the tremendous advantage which will accrue to it from a most careful and painstaking adherence to the requirements of the Underwriters, it will benefit in the future from the supervision of the National Board as it has in the past.

To-day the acetylene industry is one of the few commercial organizations which has been big enough to realize the advantages of laying a broad foundation on quality by accepting the suggestions of the insurance engineers, and the rapid advance of acetylene as an illuminant is largely due to the intelligence with which it has grasped the subject.

Section of Physics and Chemistry.

Explosives.

The Progressive Decomposition of Gun-Cotton During Its Storage.

By M. M. O. Silberrad and R. C. Farmer.

(Zeitschrift für Schiess und Sprengstoffwesen, 1907, p. 61.)

Translated from the Moniteur Scientifique of January, 1908,

By W. J. Williams, F.I.C.

The spontaneous decomposition of explosives with a nitric ester base begins at the ordinary temperature, in distinction to what takes place with true nitro-substitution compounds, such as picric acid. The progressive course of this decomposition has not yet been the object of systematic research, therefore we have undertaken certain experiments in this direction; experiments which have been to some extent made on a grand scale, using several hundred kilograms of explosives. They were carried out at different temperatures in large thermostats at constant temperature. The access of humidity, which exerts a *very* great influence on the decomposition, has been varied by different means. These researches have given the following results:

1. Physical modifications produced during storage. The ex-

terior indications of decomposition are not apparent, as a rule, until it has progressed to such a point that no conclusion can be drawn as to the degree or extent of the decomposition. The most characteristic points as to the decomposition of gun-cotton are:

a. The odor of nitrogen dioxide; if residues of ether and alcohol are present, the odor of ethyl nitrite is also apparent.

b. The action of the oxides and acids of nitrogen is shown on the wrappers, in this sense that the silk paper envelope of the cartridges is strongly attacked. Oiled paper behaves similarly, The sulphur contained in rubber (caoutchouc) wrappers is converted by the nitrogen oxides into sulphuric acid, which greatly accelerates decomposition. This is the reason why wrappers of this kind should not be used.

c. The appearance varies greatly with the conditions of storage. Sheets of gelatinized (colloided) nitro-cellulose stored in dry air curl up little by little, become brittle, and porous on their exterior, and streaks appear on their surfaces. In proportion as the decomposition progresses the color deepens strongly and sometimes becomes almost black. In moist air, deliquescent acid products are produced by hydrolysis, which make the surface glutinous, and greedily attract water. The interior of these pieces changes finally to a semi-crystalline nucleus, composed essentially of oxalic acid. On the surface the gun-cotton loses its explosive properties little by little, and burns with great difficulty leaving an interior and exterior annular ring of incombustible matter. Although these phenomena appear to a certain degree in dry air, they are more especially observable in moist air.

2. The influence of storage on the chemical composition is shown by the following changes:

a. The material suffers a progressive but constant loss of weight, which is not caused by the volatilization of the residual volatile solvents, for their value in percentage does not change. This loss is chiefly due to the decomposition of the nitric esters.

b. The content of nitrogen suffers a proportional diminution from the formation of nitrogen oxides which are set free.

c. The proportion of nitro-cellulose, soluble in ether-alcohol, increases while the proportion of insoluble nitro-cellulose decreases simultaneously. The reason of this is that the decomposition produces compounds soluble in ether-alcohol.

d. The slight increase of the residue insoluble in acetone is similarly due to the formation of products of decomposition insolution is acetone and not to the re-transformation of nitro-cellulose back to cellulose.

e. Water extraction furnishes a means of measuring the degree of decomposition of gun-cotton; for the products of decomposition are for the greater part soluble in water, as Silberrad and Farmer have recently shown.*

f. The heat test gives figures lower and lower proportionately as the decomposition progresses; however the coloration of the reagent paper may have been produced by acid bodies already formed before the heat test commenced.

3. The speed of decomposition is increased by the nitrogen oxides formed during the actual decomposition, that is to say, this is a case of auto-catalysis. This fact is clearly shown by the following figures which show the percentage loss of nitrogen for each three months' period of storage.

4. The degree of humidity of the atmosphere plays a great part both as to the speed and as to the nature of the decomposition. Other things being equal the decomposition is far more rapid in a damp atmosphere. In so far as concerns the nature of the decomposition, in the presence of moisture and on account of hydrolysis, hygroscopic oxy-acids are formed which make the inflammation of the powder so difficult, that in such a case it is hardly possible to have spontaneous ignition.

5. The influence of humidity again makes itself felt by falsifying the results of the heat test. The nitrogen acids, which are easily formed by the action of water, react on the test-paper even when the powder is entirely unchanged, at least so far as its ballistic results are concerned. This fact has been verified by experiments (see table 26). But even when the ballistic properties are changed, the powder does not show any tendency to ignite spontaneously. In this respect the decomposition set up in the presence of water is of little danger, but it should be prevented as far as possible, on account of the great speed with which it progresses, and which greatly reduces the time during which the powder is effective.

---

*Jour. Chem. Soc., 1906, p. 89 and 1182.

LOSS OF THE PERCENTAGE OF NITROGEN OF THE NITRO CELLULOSE.

	Variation in the proportion of nitrogen.			
	Experim't at 60°C. in dry air.		Experim't at 49°C. in damp air.	
	1st period of 3 mos.	2d period of 3 mos.	1st period of 3 mos.	2d period of 3 mos.
Nitro cellulose powder No. 53	—0.1	—0.5	—	—
" " " " 62	—	—	+0.2	—3.9
" " " " 63	0.0	—0.5	0.0	—0.1
Flameless " " 72	—0.1	—2.0	—0.4	—4.7
" " " 73	—0.3	—3.0	—1.9	—
Pyro-collodion	—0.2	—0.9	—2.3	—3.9
" " for 6″ R.F. guns	—0.1	—0.5	—2.9	—4.0
" " for 4″ R.F. guns	—0.3	—0.6	—1.2	—3.9
" " for 8″ guns	0.0	—0.2	—0.1	—1.7

6. The influence of temperature is extremely great. Experiments have shown that the speed of decomposition is doubled for each rise of temperature of 5°C. Hence a powder stored at 40° C. should be examined sixteen times as often as powder stored at 20°C. to obtain the same degree of security. Powders that have been manufactured according to modern rules and precautions can be stored practically for an indefinite time at temperatures below 15°C.

EXPERIMENTAL PART.

Method of Storage.—To approach as nearly as possible the conditions in force at powder factories, powders should be stored in magazines kept at a constant temperature. To remain unaffected by the position of the heating arrangements and to protect the magazines from their reciprocal influence, the localities are isolated from each other and surrounded by mounds of earth. Each magazine consists of a room lined internally with zinc and covered externally with a convenient thickness of some material insulating from heat. The chambers are covered with thin plates of corrugated iron. There is a passage-way between each two. The dimensions are—

Length.....2.40 meters.
Breadth.....1.40 " (occasionally 2 meters).
Height.....2.80 "

The chambers contain little bullseyes (peep-holes) of double glass, corresponding to the outside windows, which permit the

reading of the temperature shown by the thermometers placed inside. The reading is made from outside with the help of a lens. The cold chamber, kept at —18°C., was of the same internal dimensions, but was lined with a thicker insulating bed (30 centimeters of pieces of wood charcoal).

The heating was done by steam-coils, generally in a dry atmosphere. In some experiments the air was saturated with moisture by placing the heating coils in a vessel of water and introducing some of the steam (vapor) directly into the rooms.

The exact regulation of the temperature of such large thermostats was naturally attended with considerable difficulties. It was finally effected by a steam valve and an electro magnet. The heating was done by a principal steam-pipe and by a second smaller pipe, in which the steam circulated independently of the first pipe, and on which the regulating valve was placed. The principal pipe was not quite sufficient to keep the desired temperature, and under normal conditions the valve of the smaller pipe was a trifle wider open than was necessary to maintain the desired temperature. Under these conditions, it is easily understood that all that is necessary is to have an automatic arrangement which closes the valve of the small pipe when the temperature is too high, and reopens it when it falls. This arrangement consists of a thermometer with a spiral-shaped reservoir filled with mercury and placed in the chamber; when the temperature rises too high, the mercury closes an electrical circuit of low voltage which starts a small relay. This relay closes the principal current in which the electromagnet stands. The motion imparted to the iron core of the electro magnet is multiplied by a lever and transmitted to the steam-valve which closes itself. The temperature falls a little, then the same action re-commences in inverse order. By this means the temperature can be kept constant to approximately $\pm$ 1°C. The use of a relay is necessary, for the thin column of mercury can only carry a very weak current quite insufficient to start the electro-magnet.

Granting that smokeless powders are constituted of a colloidal mixture of different nitric ethers and cellulose, it is inevitable that they should show differences of composition in their mass, no matter how great care is taken to thoroughly mix the gelatinized mass. To give an idea of the consequent uncertainty as to the composition, which exercises an enormous influence on the results

of these storage experiments, different pieces of the same powder were analyzed, and even different parts of the same piece. A nitro-cellulose was chosen moulded in tubes of 8.75 m/m in diameter, and pieces with as much external difference as possible were taken. Control analyses were made from samples taken from the two extremities of the same piece.

The results of these analyses are given in the following tables, Nos. 1 and 2.

It will be noticed that the different ends of the same tube are generally identical. Different tubes, however, sometimes present notable differences. In spite of this circumstance, to draw exact conclusions from these storage experiments, each analysis should be made on a well-chosen average sample.

Experience has shown that the best way of choosing a fair average sample is as follows: A bundle of tubes is taken, sufficient in quantity to make all the analyses required in the course of the experiment, by tying together a certain number of sticks of nitro-cellulose powder. The end of these tubes is sawn off, as a sample of the material which has not been heated, the remainder is placed in the magazine with the rest of the lot. When the experiment is ended, an equal length is sawn off for analysis. Thus comparable results are obtained.

ANALYTICAL RESULTS.

A. Experiments on the Large Scale.—The figures given in tables I to VII were obtained from experiments carried out on very large quantities of colloided powder stored in the magazines above described. The results are reported on the substance free from ash.

The proportion of volatile constituents was determined on finely powdered material, air-dried. The volatile matter was determined by the loss of weight after twenty-four hours' dessication at 80°C. The nitrogen was determined by Lunge's method (nitrometer.) The aqueous extract was obtained by extracting the powdered substance with boiling water for one hour in a Soxhlet apparatus. The aqueous solution was then evaporated and the residue dried to 80°C. to constant weight. All the figures reported are the mean of two concordant results.

VARIATIONS IN THE COMPOSITION OF COLLOIDED NITRO-CELLULOSE.

	Percentage of sample taken						Percentage of sample taken					
	Clear tubes.		Average.		Dark.		Clear tubes.		Average.		Dark.	
Insoluble in ether alcohol..	7.82	7.72	6.84	6.20	12.80	13.10	8.05	7.93	6.91	6.44	13.80	13.61
Soluble " " ..	89.0	89.25	89.29	89.71	82.89	82.38	91.58	91.68	92.86	93.25	86.12	85.55
Insoluble in acetone.....	0.36	0.38	0.22	0.29	0.56	0.82	0.37	0.39	0.23	0.31	0.58	0.84
Volatile constituents.....	2.82	2.65	3.65	3.80	3.75	3.70						
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00 (Sic)	100.00
Nitrogen	11.98	12.05	11.92	11.86	11.79	11.80	12.34	12.38	12.38	12.43	12.25	12.26
Ash	1.02	1.87	0.60	0.72	0.73	0.78	1.05	0.89	0.89	0.75	0.76	0.81

TABLE III.

NITRO-CELLULOSE COLLOIDED BY ETHER-ALCOHOL.

Exposed 12 hours daily to moist air at 46°C. Tubes 77 c/m long, 8.75 m/m external diameter, and 3.55 m/m internal diam.

How Stored.	Quantity.	Duration of storage.	Heat test at 82.8°C. minutes	Loss of weight.	Results of analysis.	Soluble in ether alcohol.	Insoluble in ether alcohol.	Insoluble in acetone.	Aqueous extract.	Volatile constituents.	Nitrogen.
		Before storage	26	—	% on original material.	85.58	10.18	0.42	0.20	3.82	11.90
					% on dry material.	88.97	10.59	0.44	0.21	—	12.32
Tin cases hermetically soldered.	Small lot	6 mos.	7	0.44	% on original material.	89.15	6.77	0.64	1.02	3.44	11.67
					% on dry material.	92.33	7.01	0.66	1.05	—	12.09
Iron cases hermetically sealed.	78.5 k.g.	6 mos.	4	0.36	% on original material.	88.32	7.44	0.72	1.92	3.52	11.94
					% on dry material.	91.55	7.71	0.74	1.90	—	12.38
In wooden cases.	94 k.g.	6 mos.	¾	0.32	% on original material.	86.06	7.31	2.37	2.69	4.26	11.38
					% on dry material.	89.89	7.63	2.48	2.81	—	11.89
Open to the air.	78.5 k.g.	6 mos.	¾	0.40	% on original material.	89.59	5.64	0.74	1.81	4.03	11.81

TABLE I.

NITRO-CELLULOSE COLLOIDED BY ETHER ALCOHOL.

(Tubular rods 77 c/m long, 8.75 m/m external diameter, and 3.55 m/m internal diameter.

(1) Storage at—18°C. Quantity stored 313 kilograms. Cartridges 15.2 c/m long, wrapped in silk tissue, in wooden cases.

Time of storage or heating.	Loss of weight during storage in %.		Soluble in ether alcohol.	Insoluble in ether alcohol.	Insoluble in acetone.	Volatile constituents.	Content of nitrogen.	Aqueous extract.	Heat test (minutes) at 82.8°C.	Physical properties.
Not heated	—	% on original material.	—	—	0.42	3.82	11.85	0.20	26	No visible change.
		% on dry material.	—	—	0.44	—	12.32	0.21	—	
6 months	—	% on original material.	—	—	—	3.55	11.80	—	21	
		% on dry material.	—	—	—	—	12.23	—	—	

(2) Storage in dry air at 38°C. Weight 720 kilograms. Cartridges 15.2 c/m. Wrapped in silk tissue, in wooden cases.

Not heated	—	% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	Slight modification of the physical properties. The black silk tissue not attacked. Faint smell of ethyl nitrite.
		% on dry material.	88.97	88.97 (Sic)	0.44		12.32	0.21	—	
4½ months	—	% on original material.	—	—	—	2.99	11.91	—	13	
		% on dry material.	—	—	—	—	12.28	—	—	
9 months	—	% on original material	—	—	—	3.31	11.73	—	5	
		% on dry material	—	—	—	—	12.13	—	—	
10½ months	—	% on original material	—	—	—	3.29	11.71	—	2	
		% on dry material.	—	—	—	—	12.10	—	—	
12 months	6.75	% on original material.	86.91	86.91 (Sic)	0.63	3.13	11.41	0.55	3	
		% on dry material.	89.72	89.72 (Sic)	0.65	—	11.77	0.57	—	

(3) Storage in dry air at 49°C. Weight 251 kilograms. Cartridges 15.2 c/m. Wrapped in silk tissue.

		Reported								
Not heated	0	% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	The external aspect suffered no important change during storage. A faint smell of ethyl nitrite.
		% on dry material	88.97	10.50	0.44	—	12.32	0.21	—	
3 months	1.93	% on original material.	86.08	10.17	0.37	3.38	11.90	—	8	
		% on dry material.	89.10	10.52	0.38	—	12.32	—	—	
6 months	2.40	% on original material	—	—	0.35	3.15	11.87	—	9	
		% on dry material.	—	—	0.36	—	12.20	—	—	

(4) Storage in dry air at 54.4°C. Weight 251 kilograms. Stored in wooden cases with a wrapper of silk tissue and rubber.

Not heated	0	% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	After storage the tubes became brittle and porous. Their color varied from yellow to dark brown. A smell of nitrogen oxides and of ethyl nitrite.
		% on dry material.	88.97	10.50	0.44	—	12.32	0.21	—	
4½ months	—	% on original material.	—	—	—	2.96	11.81	—	2	
		% on dry material.	—	—	—	—	12.17	—	—	
10½ months	—	% on original material.	87.64	7.03	1.77	3.56	11.37	—	—	
		% on dry material.	90.87	7.30	1.83	—	11.18	—	—	
12 months	9.46	% on original material.	89.63	3.37	2.36	4.64	10.08	11.53	¾	
		% on dry material.	94.00	3.53	2.47	—	10.56	12.08	—	

(5) Storage at 54.4°C in moist air. Weight 272 kilograms. Packed in 100 lb cases. Packed in oiled paper with a rubber wrapper.

Not heated		% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	At the end of 5¼ months the powder became glutinous on the surface and strongly acid. That placed in the upper part had lost most of its nitrogen and burned with difficulty leaving a carbonaceous residue.
		% on dry material.	88.97	10.59	0.44	—	12.32	—	—	
3 months	—	% on original material.	86.63	9.87	0.38	3.62	11.90	—	8	
		% on dry material.	89.88	9.72	0.40	—	12.34	—	—	
5¼ months	—		—	—	—	3.32	11.19	3.90	—	
			—	—	—	—	11.56	4.03	—	

(6) Storage at 60°C. in dry air. Weight 251 Kilograms. Packed in cases.

Not heated		% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	The powder ignited spontaneously one day after the last sample was taken. It gave 50.5% alcoholic extract on the original weight. No marked change in the physical properties at the end of 9 months, but in about 10¾ months, just before it ignited spontane-
		% on dry material.	88.97	10.59	0.44	—	12.32	0.21	—	
4½ months	—	% on original material.	—	—	—	2.87	11.89	—	1¼	
		% on dry material	—	—	—	—	12.24	—	—	
9 months		% on original material.	—	—	—	3.08	11.35	—	½	
		% on dry material.	—	—	—	—	11.81	—	—	
10¾ months	28.2	% on original material	91.13	1.33	2.44	5.10	9.80	30.15	in the cold	
		% on dry material.	96.03	1.40	2.57	—	10.32	31.74	—	

(5) Storage at 54.4 C. in moist air. Weight 272 kilograms. Packed in 100 lb. cases. Packed in oiled paper with a rubber wrapper.

Not heated		% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	At the end of 5¼ months the powder became glutinous on the surface and strongly acid. That placed in the upper part had lost most of its nitrogen and burned with difficulty leaving a carbonaceous residue.
		% on dry material.	88.97	10.59	0.44	—	12.32	—	—	
3 months	—	% on original material.	86.63	9.87	0.38	3.62	11.90	—	8	
		% on dry material.	89.88	9.72	0.40	—	12.34	—	—	
5¼ months	—		—	—	—	3.32	11.19	3.90	—	
			—	—	—	—	11.56	4.03	—	

(6) Storage at 60°C. in dry air. Weight 251 Kilograms. Packed in cases.

Not heated		% on original material.	85.58	10.18	0.42	3.82	11.85	0.20	26	The powder ignited spontaneously one day after the last sample was taken. It gave 50.5% alcoholic extract on the original weight. No marked change in the physical properties at the end of 9 months, but in about 10¾ months, just before it ignited spontaneously, it became very brittle, and fell to dust on the slightest pressure. The tubes were yellow or black and smelled strongly of nitrogen oxides and of ethyl nitrite.
		% on dry material.	88.97	10.59	0.44	—	12.32	0.21	—	
4½ months	—	% on original material.	—	—	—	2.87	11.89	—	1¼	
		% on dry material.	—	—	—	—	12.24	—	—	
9 months		% on original material.	—	—	—	3.98	11.35	—	½	
		% on dry material.	—	—	—	—	11.81	—	—	
10¾ months	28.2	% on original material	91.13	1.33	2.44	5.10	9.80	30.15	in the cold	
		% on dry material.	96.03	1.40	2.37	—	10.32	31.74	—	

TABLE II.

NITRO-CELLULOSE COLLOIDED BY ETHER-ALCOHOL.

Tubes 105.5 c/m long, 13.6 m/m external diameter, and 6.20 m/m internal diameter.

(1) Storage at 54.4°C. in dry air. Powder exposed to the air without packing.

Not heated	—	% on original material.	80.92	14.24	0.45	4.39	11.78	—	56	
		% on dry material.	84.92	14.90	0.47	—	12.32	—	—	
9 months	—	% on original material.	84.24	11.49	0.57	3.70	11.80	—	1	
		% on dry material.	87.48	11.93	0.59	—	12.31	—	—	

(2) Storage at 60°C in dry air 420 kilograms of powder exposed to the air.

Not heated		% on original material.	80.92	14.24	0.45	4.39	11.78	—	56	The physical aspect of the nitro-cellulose after storage showed a slight decomposition. The tubes were a little twisted and porous. When broken they smelled of ethyl nitrite. The alcoholic extact at the end of 10¾ months was 12.76% of the original material.
		% on dry material.	84.63	14.90	0.47	—	12.32	—	—	
4½ months	—	% on original material.	—	—	—	—	11.80	—	2	
		% on dry material.	—	—	—	3.16	12.10	—	—	
6 months		% on original material.	85.21	11.09	0.51	—	11.66	—	½	
		% on dry material.	88.02	11.46	0.52	3.19	12.04	—	—	
10¾ months	3.55	% on original material.	87.82	6.60	1.71	—	11.45	—	¾	
		% on dry material.	91.34	6.87	1.79	—	11.91	—	—	

TABLE IV.

NITRO-CELLULOSE COLLOIDED BY ETHER-ALCOHOL STORED IN DRY AIR AT 38°C

Tubes 77 c/m long, 8.75 m/m external diameter, and 3.55 m/m internal diameter.

How stored.	Quantity.	Period of storage.	Heat test at 71.1°C. minutes.	Loss of weight.	Results of analysis.	Soluble in ether alcohol.	Insoluble in ether alcohol.	Insoluble in acetone.	Volatile constituents.	Nitrogen.
		Before storage	6	—	% on original material.	84.28	11.59	0.55	3.58	11.99
					% on dry material.	87.41	12.01	0.57	—	12.44
Tubes in glass hermetically sealed with wax.	Small quantity.	6 mos.	4	0.056	% on original material.	87.75	8.37	0.78	3.10	11.75
					% on dry material.	90.56	8.64	0.80	—	12.13
In hermetically seal-iron cases.	157 k.g.	6 mos.	6	0.348	% on original material.	86.21	10.90	0.42	2.47	11.83
					% on dry material.	88.39	11.18	0.43	—	12 13
In defective iron cases.	157 k.g.	6 mos.	3	0.749	% on original material.	—	—	0.44	2.63	11.69
					% on dry material.	—	—	0.45	—	12.00
Packed in wood, with cover (lid) laid over.	157 k.g.	6 mos.	5	1.58	% on original material.	85.36	11.62	0.57	2.45	11.65
					% on dry material.	87.51	11.91	0.58	—	11.94

TABLE V.

NITRO-CELLULOSE COLLOIDED BY ETHER-ALCOHOL, STORED AT A CONSTANT TEMPERATURE OF 60°C. IN DRY AIR.

Tubes 72 c/m long, 7.84 m/m external diameter and 3.64 m/m internal diameter. Density before drying 1.584. Average weight of tubes 44.0 gr.

How stored.	Quantity.	Period of storage.	Nitrogen %.	Ash %.	% of moisture on leaving storage.	Heat test at 85°C. minutes.	Time when brown fumes showed at 135°C. Minutes.
——	——	Before storage	12.45	0.27	1.35	14	60+
In closed cartridges.	9 k.g.	3 months.	12.41	——	1.28	13	60
In open cartridges.	9 k.g.	3 months.	12.37	——	0.80	11	60
In cartridges placed in an ordinary wooden box.	9 k.g.	3 months.	12.33	——	0.43	10	60

TABLE VII. (Sic.)

NITRO-CELLULOSE COLLOIDED WITH ETHER-ALCOHOL STORED AT 45.5°C. IN A DRY ATMOSPHERE.

The results are the mean of concordant experiments.

Dimensions of tubes in glass				Time of Storage in months								
Length	External dia.	Internal dia.		0	3	6	9	12	15	18	21	24
cm.	mm.	mm.	Zinc iodide test at 80°C (min.)	30 +	45	50–60 and more	48	24	25	39	46	34
230	4.5	3.0	Ignition test in °C	176¼°	176¼°	176½°	178¼°	176¾°	175°	176¼°	175½°	176½°
			Nitrogen %	11.75								11.73
785	12.5	4.5	Zinc iodide test at 80°C (min.)	30 +	9	60 +	60 +	60 +	4	5	7	4
			Ignition test	177¾°	177½°	177°	173¾°	177¼°	175½°	175¾°	175½°	176°
			Nitrogen %	12.38				12.36				12.32
128	4.0	1.5	Zinc iodide test at 80°C (min.)	30 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +
			Ignition test	175¾°	173½°	173½°	173½°	175¾°	175¾°	176¼°	174¾°	174½°
			Nitrogen %	12.43				12.25				12.42
126.7	2.6	0.7	Zinc iodide test at 80°C (min.)	30 +	60 +	60 +	60 +	60 +	60 +	60 +	60 +	10
			Ignition test	176°	175½°	175°	176¼°	177°	177°	177°	176°	175¼°
			Nitrogen %	12.28				12.24				12.38

B. EXPERIMENTS ON STORAGE IN A DRYING-ROOM (OVEN).

If the preceding results are compared with those obtained when working on small quantities, it is evident that 100 grams give sufficiently exact results. Consequently powder has been effectively stored in boxes of 100 grams, kept at a constant temperature in a dry-house, that is to say:—

(1) At 60°C. in dry air,

(2) At 49°C. in moist air.

The temperature was maintained constant to about 1°C. by means of Scheibler's regulator.

The choice of samples was made as has been previously described. In the case of tests made in moist air, the bundle of tubes was undone after the test and the powder was dried for twenty-four hours at 38°C. before being weighed. We only reproduce here some of the twenty-five tables contained in the original work.

TABLE XII.

NITRO-CELLULOSE POWDER, NO. 53.

Colloided tubes, external diameter 7.06 m/m, internal diameter 2.98. A uniform color of clear chocolate brown.

	Not Heated.	3 mos. at 60°C. in dry air.	6 mos. at 60°C. in dry air.	3 mos. at 49°C. moist air.	6 mos. at 49°C. moist air.
Physical changes.		Appearance unchanged, slight smell of nitrous ether.	Appearance unchanged, smell of nitrous ether and of nitrogen peroxide.	Partially covered with mould; otherwise unchanged. Slight smell of vaseline.	Slight irregularity Smell as before.
Reaction with litmus paper.	Neutral.	Paper red.	Paper red.	Paper red.	Paper red and partially discolored.
Loss of weight %	0	2.15	6.12	—	—
Nitrogen % on original material.	11.64	11.57	11.05	—	11.57
On dry material.	11.92	11.84	11.34	—	11.75
Aqueous extract % on original material.	0.89	0.92	5.66	—	1.07
On dry material.	0.91	0.94	5.81	—	1.09
Heat test at 71°, Minutes.	12½	6½	2	—	20
Ignition.	181°	181°	178.5°	—	183°
Temperature °C.	181.5°	181°	178°	—	183°

TABLE XIII.

NITRO-CELLULOSE POWDER, WITH 2% OF VASELINE ADDED, NO. 62.

Colloided tubes, external diameter 5.15 m/m, internal diameter 2.37 m/m. Color, brown, slightly reddened; no spots. Smell resembles vaseline.

	Not Heated.	3 mos. at 60°C., dry air.	6 mos. at 60°C., dry air.	3 mos. at 49°C., moist air.	6 mos. at 49°C., moist air.
Physical changes.	—	Appearance unchanged, slight smell of nitrogen peroxide.	Slight irregularity; strong smell of nitrogen peroxide.	Appearance and smell unchanged.	Color much clearer. Very irregular marks and marbling. Smell of nitrogen peroxide.
Reaction with litmus paper	Neutral.	Paper reddened.	Paper reddened.	Neutral.	Paper discolored.
Loss of weight %.	0	1.48	6.23	1.85	—
Nitrogen on original material %.	11.47	—	11.56	11.85	7.62
On dry material %.	11.72	—	11.43	11.87	8.00
Aqueous extract on original material %.	0.90	—	2.33	1.33	15.61
On dry material %.	0.92	—	2.41	1.35	15.39
Heat test at 71°, Minutes.	66	48	2½	34	¾
Ignition.	181°	181°	180°	182°	180°
Temperature	179.5°	181°	179.5°	182.5°	180.5°

TABLE XIX.

SMOKELESS POWDER IN OPEN CARTRIDGES (GERMAN).

Small crosses, not colloided. Greatest length 12 m/m. Peculiar smell, recalling that of alcohol.

	Not Heated.	3 mos. at 60°C., dry air.	6 mos. at 60°C., dry air.	3 mos. at 49°C., moist air.	6 mos. at 49°C., moist air.
Physical changes.	——	Appearance and smell practically unchanged.	Color a little clearer; no smell.	Appearance and smell practically unchanged.	No change; no perceptable smell of nitrogen peroxide.
Reaction with litmus paper	Neutral.	Paper red.	Paper red.	Paper discolored.	——
Loss of weight %.	0	3.69	4.96	1.57	——
Nitrogen on original material %.	12.56	12.38	12.54	12.48	12.28
On dry material %.	12.66	12.50	12.65	12.58	12.53
Aqueous extract % on original material %.	1.58	1.58	1.80	1.08	2.83
On dry material %.	1.60	1.60	1.82	1.09	2.89
Heat test at 71°C. Minutes.	6	11½	4½	20	6½
Ignition. Temperature °C.	179°	184°	180.5°	184°	167°
	179.5°	184°	180.5°	184.5°	168°

TABLE XXIV.

PYRO-COLOIDON (U. S. ARMY) FOR 8″ FIELD GUNS.

Multitubular, colloided. Diameter 13.86 m/m. Clear brown surface, smooth and somewhat translucent. Slight smell.

	Not Heated.	3 mos. at 60°C., dry air.	6 mos. at 60°C., dry air.	3 mos. at 49°C., moist air.	6 mos. at 49°C., moist air.
Physical changes.		Appearance unchanged; distinct smell of nitrogen peroxide.	A little warped; longitudinal cracks; strong smell of nitrogen peroxide.	Appearance considerably changed. Color faded and opaque; deliquescent white spots; distinct smell of nitrogen peroxide.	Decomposition still more distinct; color almost white; deliquescent and quite decomposed; strong smell of nitrogen peroxide.
Reaction with litmus paper	Neutral.	Paper red.	Paper red and partially discolored.	Discolored.	Discolored.
Loss of weight %.	0	2.51	4.51	2.85	22.28
Nitrogen % on original material %.	11.36	11.46	11.34	11.26	9.57
On dry material %.	11.73	11.76	11.59	11.65	9.98
Aqueous extract % on original material %.	1.14	1.10	2.58	1.13	1.27
On dry material %.	1.17	1.13	2.64	1.17	1.32
Heat test at 71°C. Minutes.	32½	½	—	In the cold.	In the cold.
Ignition. Temperature °C.	182.5° 189°	175.5° 176°	181.5° 182°	180° 179°	180.5° 180°

INFLUENCE OF MOIST AIR ON THE BALLISTIC QUALITIES.

The following experiments show how greatly the figures given in the heat-test may be lowered while the ballistic properties remain practically the same.

FIRING TEST OF NITRO-CELLULOSE POWDER STORED AT 46°C.

IN MOIST AIR.

	How packed.	Weight of charge k.g.	Temp. of charge °C.	Initial velocity ft. per sec.	Pressure Tons per sq. in.	Heat test at 82°C., min.
Not heated.		15.649	27°	2763	15.20	26
" "		"	26°	2720	14.35	
" "		"	26°	2741	14.75	
After 6 mos.	In hermetically closed iron.	"	26°	2791	15.80	4
" "	" "	"	26°	2783	15.85	
" "	" "	"	26°	2768	15.50	
" "	" "	"	26°	2817	16.50	
" "	" "	"	26°	2792	15.30	
" "	In wood	15.618	27°	2718	15.10	¾
" "	"	15.645	27°	2725	15.10	
" "	"	15.413	27°	2738	15.80	
" "	"	15.411	27°	2702	14.90	
" "	"	15.547	27°	2734	15.05	
When the powder has been freely exposed to moist air its influence on the ballistic properties can be recognized as the following figures show:						
Not heated.	Ordinarily.	15.649	26°	2741	14.75	0¾
After 6 mos.	Exposed to moist air.	15.521	26°	2702	14.40	
" "	" "	15.521	26°	2645	13.55	
" "	" "	15.521	26°	2584	13.00	
" "	" "	15.521	26°	2580	13.10	

Book Notices.

A Text-Book of Physics, edited by A. Wilmer Duff. Contributors: A. Wilmer Duff, Karl E. Guthe, William Hallock, E. Percival Lewis, Arthur W. Goodspeed, Albert P. Carman, R. K. McClung. P. Blakiston's Son & Co., Philadelphia. Cloth, 680 pages, 6 x 8½ inches, 511 illustrations. Price, $2.75 net.

It is scarcely possible with the present-day development of a broad subjest like physics to attain the highest efficiency in the production of a text-book by the unaided effort of a single author. In the preparation of this work an appreciation of the value of concerted effort is evidenced by the

colaboration of seven contributors, each responsible for a distinct division of the subject.

The arrangement of topics follows the usualy accepted order, Mechanics Properties of Matter, Heat, Wave, Motion and Sound, Electricity and Magnetism, Electro-Magnetic Induction, Conduction of Electricity through Gases and Radioactivity. These are treated with a thoroughness consistent with the limitations of a general text-book, elaboration having been avoided without the omission of essentials.

The deductions made are satisfying without being too profound and numerous illustrative problems are given at the end of each chapter. These, particularly, enhance its value as a general text-book. The important matter of an index has not been neglected—an index of names and subjects is given.

The type is clear and cuts well executed. E.

Internal Combustion Engines, their Theory, Construction and Operation. By Rolla C. Carpenter, M.M.E., L.L. D., and H. Diedrichs, M.E. D. Van Nostrand Company, New York. xiv, 597 pages, 6¼x9½ inches, with numerous illustrations and tables.

The author's aim has been to develop the subject in a logical order and in the simplest terms possible.

Beginning with classification and definition, thermodynamic principles are discussed and applied, then combustion and fuels and apparatus for their utilization are treated. At this point a historical sketch of the origin and development of the gas engine is given. Then follows a detailed account of the various types of modern engines and their auxiliaries. Methods of power estimation, testing engines and producers and costs are covered in the final chapters. While theoretic principles have been freely considered the work is really only the more practical from the many and related numerical deductions which follow.

The complete and fully illustrated section on types, details and operation of modern engines is valuable even to one seeking general information only. In this the structural features of design are very properly omitted. The chapter on cost data and detailed estimates of cost is an unusual and welcome addition to a treatise of this kind.

The work as a whole is a well arranged treatise which may be safely recommended for a thorough course on this subject. L. E. P.

Road Preservation and Dust Prevention. By Wm. Pierson Judson, Consulting Engineer. Engineering News Publishing Company, New York. Cloth, 6 x 9 in., 144 pages, 16 illustrations. Price, $1.50 net.

Dust prevention and road preservation form one of the vexed problems of the day, and a work devoted specifically to the subject should make a welcome addition to the literature of highway engineering.

The conditions producing dust and methods of prevention are first discussed, followed by detailed descriptions of various treatments and methods of their application. These are well illustrated by half-tone cuts.

Numerous references to original sources of information and the unit costs given for each method of treatment are features to be considered.

The subject-matter, well classified under the usual topics discussed, and a copious index enhance its value for reference.

The book is well printed and attractively bound. L.

Reinforced Concrete. A Manual of Practice. By Ernest McCullough, M.D., S.E., Civil Engineer, Chicago. Cement Era Publishing Company, 1908. Cloth, 128 pages, 5″ x 8″. Price, $1.00.

Much of the literature on reinforced concrete consists in elaborate treatises from which it is troublesome to formulate rules of practice for commercial use. In the present volume is elaborated such a set of rules of practice from which the non-essentials of the subject have been eliminated, and the author's personal experience introduced. Beams, floors, columns, retaining walls, tanks and footings are treated, and finally, costs, practical details of form and conduct of the work in the field are described at considerable length. The subject matter is thoroughly practical, clearly and forcibly expressed. The work should find a welcome place at the desk of the concrete designer. L. E. P.

PUBLICATIONS RECEIVED.

Return of the "Galilee" and construction of a special vessel by L. A. Bauer, director. Reprinted from "Terrestrial Magnetism," Vol. 13, No. 2. 2 pages, 8-vo.

The Earth's Residual Magnetic Field. A Tanakadate; L. A. Bauer. Reprinted from "Terrestrial Magnetism," Vol. 13, No. 2. 5 pages, 8-vo.

Is the Earth's Action on a Magnet only a Couple? (Preliminary report on "Results of Careful Weighings of Magnets in Various Magnetic Fields"), by L. A. Bauer. From "Terrestrial Magnetism and Atmospheric Electricity" for March, 1908. 11 pages, 8-vo.

Some Results of the Magnetic Survey of the United States, by L. A. Bauer. (Reprinted from "Science," N. S., Vol. 27, No. 699, pages 812-816, May 22, 1908.) 5 pages, illustrations, 4to.

Konstant Auftretende Secundäre Maxima und Minima in den Jährlichen Verlauf der Meteorologischen Erscheinungen von Dr. Van Rijckevorsel. Fünfte Abteilung. 14 pages, plates, 4to. Rotterdam, W. J. Van Hengel, 1908.

Bulletin du Laboratorie d'Essais Mecaniques, Physiques, Chimiques et des Machines du Conservatoire National des Arts et Metiers. No. 14. Essais de Torsion Les essais de torsion considérés comme moyens de sélection des métaux. Relations entre la torsion et la traction par Pierre Breuil. 17 pages, illustrations, plates, 8-vo. Paris, Ch. Beranger, 1908.

Palæzoic Rocks Under Southeastern England, by Edward A. Martin, F. G. S. Reprinted from "Knowledge and Scientific News." August, 1908. 11 pages, illustrations, 12-mo. London, King, Sell & Olding, 1908.

United States Department of Agriculture, Forest Service—

Circular 135. Chestnut Oak in the Southern Appalachians, by H. D. Foster and W. W. Ashe. 23 pages, 8-vo.

Circular No. 139. A Primer of Wood Preservation, by W. F. Sherfesee. 15 pages, 8-vo.

Circular No. 151. The Preservative Treatment of Loblolly Pine Cross-Arms, by W. F. Sherfesee. 29 pages, illustrations, 8-vo.

Circular 153. Exports and Imports of Forest Products, 1907, compiled by A. H. Pierson. 26 pages, 8-vo. Washington Gov't Printing Office, 1900.

United States Department of Commerce and Labor, Census Bureau. Forest Products, No. 1. Pulp Wood Consumption, 1907. Compiled in cöoperation with the Department of Agriculture, Forest Service. 14 pages, 8-vo. Washington Gov't Printing Office, 1908.

How to Build Up Furnace Efficiency, by Jos. W. Hays. Unpaged, 16-mo. Chicago, author, 1908, paper. Price, 50 cents.

Pennsylvania State College, Annual Report for the year 1906-1907. Part I, Department of Instruction. Part II, Agricultural Experiment Station. Harrisburg, State Printer, 1908.

Georgia Geological Survey, Bulletin No. 16. Second Report on the Water Powers of Georgia, by B. M. Hall and M. R. Hall. 424 pages, illustrations, plates, maps, 8-vo. Atlanta, Franklin-Turner Co., 1908.

Bulletin No. 17. Report on the Fossil Iron Ores of Georgia, by S. W. McCallie. 199 pages, illustrations, plates, maps, 8-vo. Atlanta, Franklin-Turner Co., 1908.

Pennsylvania State College Bulletin, Vol. II, No. 4, June, 1908. Proceedings of the Forty-eighth Annual Commencement and the Inauguration of Edwin Erle Sparks, Ph.D., as President of the Pennsylvania State College, June 17, 1908. 128 pages 8-vo. State College, 1908.

International Acetylene Association, Eleventh Annual Meeting, held at Auditorium Hotel, Chicago, August 10, 11, 12, 1908. 171 pages, illustrations, 8-vo. Chicago, Secretary-Treasurer, n. d.

Ontario Bureau of Mines. Report, 1907, Vol. 16, Part II. The Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming (third edition), by Willet G. Miller, Provincial Geologist. 212 pages, illustrations, maps, 8-vo. Toronto, King's printer.

Thoughts on Natural Philosophy with a new reading of Newton's First Law, by A. Biddlecombe. 24 pages, 16-mo. London, Whittaker & Co., n. d.

A history of the Origin of the Place Names in nine Northwestern States, including States, Counties, Towns, Villages and Stations connected with the Chicago and Northwestern and Chicago, St. Paul, Minneapolis and Omaha Railways. Ed. 2. Compiled by one who for more than thirty-four years has been an officer in the employ of the company. 201 pages, map, 8-vo. Chicago, 1908.

Michigan State Board of Health, thirty-fifth Annual Report of the Secretary for the year ending June 30, 1907. 188 pages, 8-vo. Lansing, State Printers, 1908.

T
1
F8
v.166

Franklin Institute,
Philadelphia
Journal

Physical &
Applied Sci.
Serials

Engineering

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE